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SURVEYS AND NEW VISIONS OF THE ANCIENT CENTRE OF NAPLES

Among the ongoing research on the ancient center of Naples, this paper offers an example of the potential of the disciplines of survey and representation that allow to critically manage the role of architecture and urban space as a memory device in the processes of vision and recognition of the image of the city.
The main goal of the research, of which a fragment is proposed here, is to recognize the configurative distribution of urban variables, through a discretization approach and multiscalar analysis that, exploiting the potential of a territorial information system, combines cartographic data, images, historical sources and new surveys and representations/visualizations derived from data segmentation and classification approaches.
The analysis and documentation activities have been applied to significant elements of the urban structure, such as the intersections of some cardo with the lower decumanus identified by Via Benedetto Croce - via San Biagio dei Librai - via Forcella, particular elements both for shapes and for dimensions. The careful use of UAV allowed the survey of the facades of buildings overlooking the narrow alleys of the ancient city that, in most cases, would be results not surveyed with laser scanning or traditional survey techniques. The successive phases of photomodelling and infographic 2D/3D restituitions have allowed to highlight, through a different approach to the reading of reality, peculiarities and volumetric proportions difficult to perceive by the pedestrian, intent to follow the narrow streets, almost sucked out of them. The post-processing phases, through the experimentation of semantic segmentation algorithms, made it possible to extract the elements and information layers of the image of the stratified city, as well as for the elaboration of drawings on an architectural and detailed scale.

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Cultural Heritage; Neapolis; UAV photogrammetry; image-based modeling; semantic segmentation

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INTRODUCTION

In the context of the research work in progress focusing on the city of Naples, the article [1] intends to offer an exemplification of the potential of the disciplines of survey and representation to critically appropriate and manage the role of architecture and urban space as a privileged memory device in the processes of vision and recognition of the city's image. In particular, mention is here made of the "Forma Urbis Neapolis" project which, articulated over a two-year programme, starts precisely from the recent hypotheses on the original form of Neapolis and from the long experience gained by CIRICE - Centro Interdipartimentale di Ricerca sull'Iconografia della Città Europea dell'Università degli Studi di Napoli Federico II - in the field of urban history and iconography of the city of Naples.
The project deploys strategies of historical-cartographic investigation with the aim of identifying all possible traces of the original forma urbis in the cartography of the modern and contemporary age, from the so-called pre-catastal phase of the viceroyal age to the bourbon age, from post-unification maps to post-World War II aerophotographic surveys. Naples today probably represents the European city that better than any other offers the opportunity for a complete analysis of the urban palimpsest, from the Greek to the contemporary age, readable as an open book through traces, memories, images of the city's form and its limits [Buccaro 2020, 563]. The complexity of a city such as Naples manifests itself in the high and heterogeneous multiplicity of the parts that constitute its essence and makes the co-presence of several disciplines' indispensable. Moreover, the method of analysis that combines cartographic data, images, historical sources and new representations in a spatial georeferencing tool that places space at the centre of morphological and evolutionary analysis is increasingly widespread today, and its main objective is to recognise the configurative distribution of urban variables of interest both for the disciplinary sector of Drawing and for the various sectors involved in research.
The analysis and documentation activities were applied to significant elements of the urban fabric, such as the intersections of the cardinals and decumans in the ancient city centre (fig. 1), which are particular both in terms of shape and size, making use of current digital technologies of three-dimensional survey that have made it possible to highlight, through a different approach to reading the built reality, geometric peculiarities and volumetric proportions that would otherwise be difficult to perceive [Parrinello, Picchio, 2019]. To document the complexity of this cultural heritage, the integration of the data acquired with image-based systems and the extraction of geometric data, through Deep Learning techniques of segmentation and classification, supports the implementation of the morphometric database in the description of the curtains. buildings and their component architectures, very complex elements because they are inserted in a context of high historical value.

Fig. 1 - The ancient centre of Naples in a view from google map. In blue the structure of the founding nucleus of Neapolis.

NEW MORPHOLOGICAL NOTES ABOUT ANCIENT CENTER OF NAPLES

Although the foundation of Neapolis, the new city that contrasted with Palepoli, has long been assigned to 470 B.C. on the basis of the juxtaposition of a historical fact, the battle of Cumae in 474 B.C., and the date of the oldest tombs in the necropolis of Castel Capuano [Longo 2017, 7]. Recently, a hypothesis of a date a few decades higher has made it possible to frame the Neapolitan urban layout in a late archaic chronological context characterised by the presence of large *plateiai* in an east-west and north-south direction that delimit elongated blocks, making it possible to identify a clear design geometry.
The structure of the founding nucleus of Neapolis, studied on several occasions in the last century e.g. by Capasso, can now be dated with certainty to the last quarter of the 6th century B.C., thanks to recent archaeological discoveries [Buccaro, Tauro 2020]. In these years, Geometry and Mathematics, Music and Medicine underwent a remarkable development, and it is not unlikely that these recent findings would have been applied to the geometric construction of a founding city, which is why it was called New [Buccaro Tauro 2020]. It is possible, in fact, to hypothesise the division of the urban layout and the delimitation of the center the true fulcrum of the polis where daily life took place, and to suppose the existence of a 'geometric theory founded on the figures of the circle and the square underly-

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ing urban planning and clearly bearing the Pythagorean rules [Tauro 2017, 17].
More specifically, in the Neapolitan case, this hypothesis can be substantiated by the integrated analysis of the morphology of the ancient slope on which the city was built, the reconstruction of the course of the Greek-age fortification and the articulation of the road network as it is known to date, on the basis of long reflections, now supported by the most recent archaeological results and by Capasso's studies on the ancient toponymy of Naples. From such studies we observe that the upper *plateia* of via Anticaglia, ex marmorata or *Summa Platea* – number 1 in fig. 2 –, (as Capasso calls it) the lower one of via San Biagio dei Librai – number 2 in fig. 2 –, ex *platea Furcillensis* and the two streets corresponding to via Duomo – number 3 in fig. 2 –, or *platea Cimbrum* or *Cimbeum* and via Atri, ex *platea Atriensis* – number 4 in fig. 2 –, delimit a large square in the centre of the urban grid. It is in turn subdivided by the central *plateia* of via dei Tribunali, ex *platea Augustalis*, into two equal rectangles, with proportional sides 1:2, the lower of which is further subdivided into two squares, by the axis of via San Gregorio Armeno, ex *platea Nustriana* [Tauro 2017, 17-19]. Orthogonally to this axis are rectangular blocks whose dimensions confirm those reconstructed by various scholars: the long side equal to 180-185 m and the short side equal to 35-38 m in a proportional ratio of 1:5; 5 blocks made up each of the 4 squares and each block contained within it 20 residential units of a square shape and 17x17m in size.
The future *platea Furcillensis* - Spaccanapoli - thus constituted a structural and at the same time visual element that was strongly connotative and clearly legible both in orthogonal projection and when observing the ancient city from above. It is no coincidence that the term 'generating line' borrowed from Geometry - with the meaning of a line giving rise to a surface moving in space - is particularly effective in synthesising the role of a creating element assumed in the foundation project: the founders of Neapolis, at the end of the 6th century B.C., after having ascended the hill of San Martino from the southern slope overlooking Parthenope,

Fig. 2 - Inside the ancient centre it is possible to identify the foundation square of the old Neapolis delimited by 4 *plateiai*.

Fig. 3 - In white the *Furcillensis platea* – Spaccanapoli – with the orthogonal streets (Via San Sebastiano, Via San Domenico, Via Nilo, Via San Gregorio Armeno, Via Duomo).

they look out over the vast plateau surrounded to the north by high hills extending at their feet and delineate an axis inclined at 22.30° east-northeast, which constitutes the straight line around which a harmonious and at the same time rigorous system of subdivision and organisation of the urban space develops. Along this axis each intersection of streets generates orthogonal levels that follow one another, intertwine, and contrast until they become a sequence of visual planes that exemplify the image of the stratified city. And it was along this axis that the survey campaign and the consequent graphic experiment took place, with the aim of offering visualisations capable of expressing the modalities underlying the processes of construction of the urban layout of a Greek city, rebalancing from time to time that relationship between theory and practice that constitutes the soul of Drawing, in the continuous passage from the imaginative phase to the graphic one. In particular, the focus was on the intersections of the *Furcillensis platea* – Spaccanapoli – with the orthogonal streets (Via San Sebastiano, Via San Domenico, Via Nilo, Via San Gregorio Armeno, Via Duomo) in which the tight rhythm of the street axis is broken by sudden cuts of light, by variations in space, shapes and sizes. The areas that are the subject of this work are marked in white on the planimetric sketch in fig. 3, where the focus of the survey work was on urban nodes,

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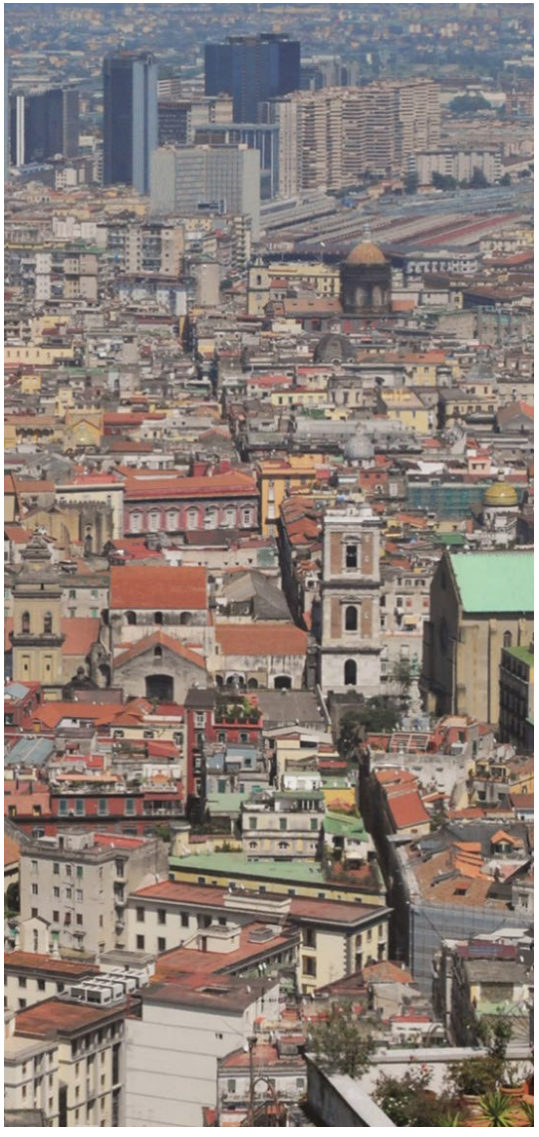

Fig. 4 - Spaccanapoli constitutes a very important line both in plan and in the vision of the city.

Fig. 5 - On the left, a part of the narrow via San Biagio dei Librai; on the right, DJI Spark during the survey phase of the right front of the church.

i.e. the intersections of the *plateiai* each other, but the work carried out is given as an example at the intersection between via San Biagio dei Librai and via San Gregorio Armeno, in correspondence with the church of San Gennaro all'Olmo.

SURVEY AND NEW VISUALIZATIONS

The urban areas under study were analyzed and surveyed through a workflow aimed at optimizing processes in the field of reconstruction and multiscalar digital representation, using digital technologies and post-processing techniques consolidated within the discipline. The digital reproduction of facades was achieved thanks to the use of UAV as well as the most reliable software platforms for three-dimensional modeling. The visualizations created – graphics, high resolution orthoimages, 3D models - have the advantage of representing and studying both narratives and numbers. In addition, they offer something more than representations of knowledge and also be able to raise new questions.

The location of the urban fragments in question, in the historic center, presented various critical issues for the survey activities, starting from the small size of the adjacent spaces (fig. 5) which did not favor an optimal terrestrial photographic capture of the upper parts of the fronts (performed with the Panasonic DMC-FZ200 camera): the inclined optical axis in vertical projection produces, in fact, unfavorable angles of incidence for the representation of the elements at the higher levels. The poor or absent GPS signal to support the flight has forced to continue the activities in completely manual mode, complicated by the constant and dangerous presence of seagulls and by gusts of wind at high altitude. In particular, 1.864

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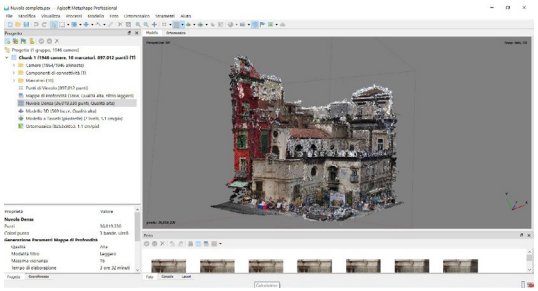

Fig. 6 - Software interface under development.

Fig. 7- Mesh model of a part of the surveyed urban fragment.

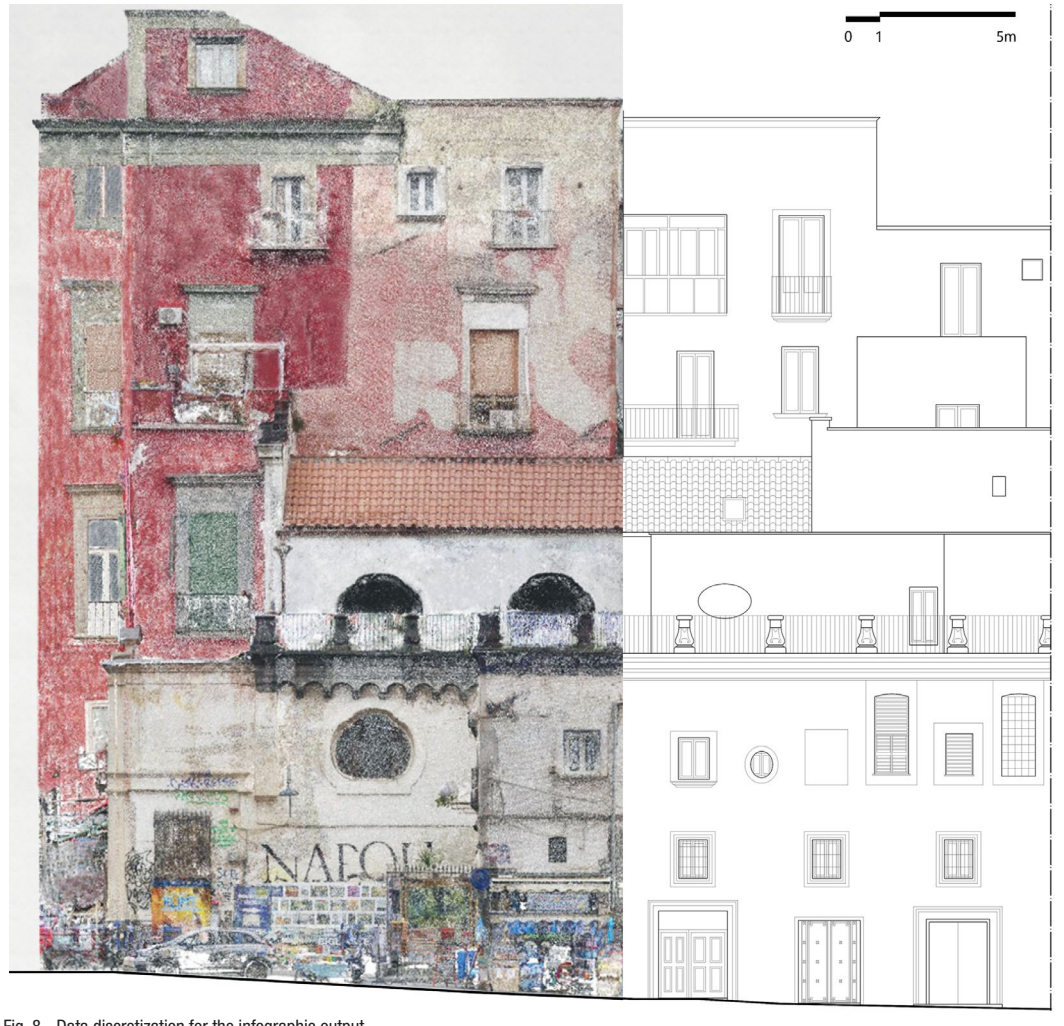

Fig. 8 - Data discretization for the infographic output

images were aligned for the fronts facing the intersection between via San Biagio dei Librai and via San Gregorio Armeno, in correspondence with the church of San Gennaro all'Olmo, of which 420 are terrestrial photos at a resolution of 4.000 x 2.248 pixels and 1.444 are 2-megapixel resolution frames taken from 1080p video. The processing of the data obtained was carried out using Agisoft Metashape software which, through Structure from Motion (SfM) algorithms, allows the geometric reconstruction of the scene by recognizing the relative and absolute positions of the cameras and their orientation (fig. 6). A sparse cloud consisting of almost 900,000 points, a dense cloud of over 36 million points, a textured mesh model (fig. 7) of almost 5 and a half million polygons and some orthoimages of the fronts were thus produced. The process, at maximum resolution, guarantee a GSD slightly lower than 1 cm/px, considered acceptable for numerical calculations on an urban and architectural scale.

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Fig. 9 - Some graphic drawings of the other fronts facing the urban fragment examined.

The infographic outputs produced in this way - and the relative relief graphics drawn by them (figs. 8-9) - allow a different visuality than the terrestrial perception of those who pass through the city. The digital interaction with the model and the possibility of viewing from different heights and at different angles highlight the proportions between the fronts of contiguous buildings, between full and empty volumes, between continuous and perforated surfaces, between the front and the back, the above and below. An almost unique spatial context within the selected case studies, characterized by tall buildings buildings located a short distance from each other and rarely, in correspondence with the few urban bends, allow themselves to be pierced by the sky and direct light; which makes it

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difficult to define common models within the same architectural class, for which the semantic segmentation of data and detection is gaining more and more attention, allowing to automatically recognize historical elements by typological classes and automate the analysis and modeling processes of transformations.

SEMANTIC SEGMENTATION FOR A DISCRETIZATION OF THE URBAN SCENE

The recent progress in survey technologies for digital cultural heritage has led to the generation of highly accurate point clouds. This allows the development of a database organized in semantically coherent segments, oriented to the digital and automatic reconstruction of architectural structures, building components, and typologies [Croce et al. pp. 829-836].
The complexity and variability of forms and geometries within the dataset, in addition to the limited repeatability of the elements – which are often unique even within the same typological class – complicates the definition of protocols of machine learning for the optimization of the documentation of the cultural heritage [Pierdicca et al. 2019, p. 203; Grilli & Remondino 2020].The aspect of the façades of historical buildings shows an evident degree of typological complexity, even more in this case study, whose building curtains are the result of urban transformation processes. Despite that, these approaches of data discretization and classification allow classifying more rapidly the variability of the conformation of architectural components and revealing the layout of voids and the presence of alignments and discontinuities in the urban fabric.
In many recent works, significant results have been obtained concerning the automatic identification of the various typologies of architectural components from the point clouds acquired through TLS or photogrammetric techniques [Grilli et al. 2019, pp 541-548; Wang et al. 2019, pp. 2671-2673; Pierdicca et al. 2020, p. 1005]. This is compounded by the recent development of pixel-based learning algorithms: despite the effort required for the hierarchical organization of unstructured point cloud data, characterized by the lack of an orderly grid, they allow analyzing patterns to extract the characteristics and information on the historicized architectural components, organized on multiple levels of cascading units, accelerating the reconstruction process of models from hierarchically classified survey data.
However, the analysis of orthophotos still has some limitations and issues concerning occlusions, shadows, deletions, and image quality, in relation to the reliability of the aerial-photogrammetric survey; hence, as in the current proposal, a key role is played by the integration of the image segmentation process with the classification of the set of points in the object space.
Hence, the current proposal is characterized by the definition of an experimental framework (fig. 10) for the semi-automated obtainment of the components of urban blocks. This facilitates the reconstruction and multiscale digital representation of the parts of the architectural model, obtaining topological-hierarchical graphs through the following phases:
- Definition and orientation of the mesh model;
- Macro-discretization and classification of the building curtains according to the depth levels of the digital model;
- Segmentation and classification of the architectural components for each façade of the urban block.
A portion of the study area has been used as a prototypal model to test the process. In the first phase, a polygonal model was generated with traditional

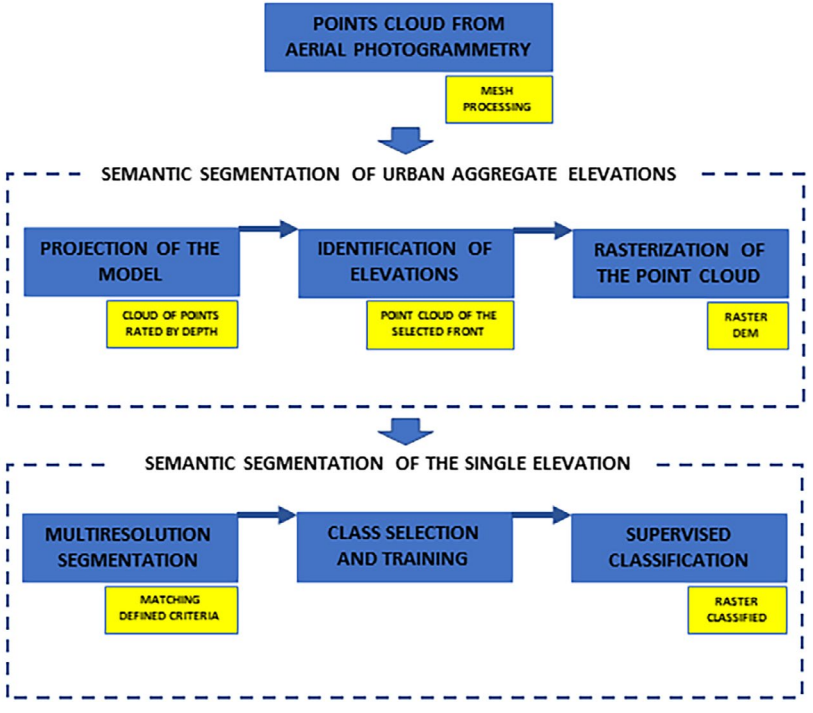

Fig. 10 - Methodological framework for the analysis and classification of aerial photogrammetric model models.

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meshing processes through direct triangulation of the spatial vertices, which is coherent with the compositional detail of the real scene, obtained through the integration of the results of aerial and terrestrial aero-photogrammetric surveys.
The goal of 'adherence' to the physical reality of the interpolation-generated model requires the morpho-metric database to go through geometry processing for data cleaning and decimation. This is related to the desired morphological detail for the description of the building curtains and their architectural components: in this first test, it was set to obtain the output of the window profiles and the geometric quality of the contour decoration elements.
Hence, the first discretization of the building curtains making up the urban block (fig. 11), was accomplished through the rasterization and classification of the polygonal vertices for the different depth levels of the model. This allowed the preliminary identification of the building curtains in terms of localization and relationship with the adjacent buildings; the range of values of the chromatic scale was particularly wide, due to the geometric gaps and non-coplanar, superimposed architectural components. This highlights the importance of the interpretation of the derived color maps and classification histograms. This procedure represents a preliminary evaluation, considering its tolerances related to the architectural and urban context. Hence, it is followed by the second phase (fig. 12) the pixel-oriented segmentation and classification process of the single building curtains.
The pixels of each image have been aggregated through a multi-resolution segmentation (fig. 13) according to the choice of the color and form criteria of the components; this led to a vectorial discretization with a minimized spectral heterogeneity for the generated polygons. Following the segmentation phase, the classification has been performed with a parallel supervised Deep Learning approach: that is, the classes have been defined in a nomenclature system, pre-established through initial training for a number of polygons, which were chosen as the targets of the supervised classification of the areas. The testing of the classified unit has led to the definition of the first classification of the main components, that is doors and windows, which are useful in the graphical analysis of the partitions which have

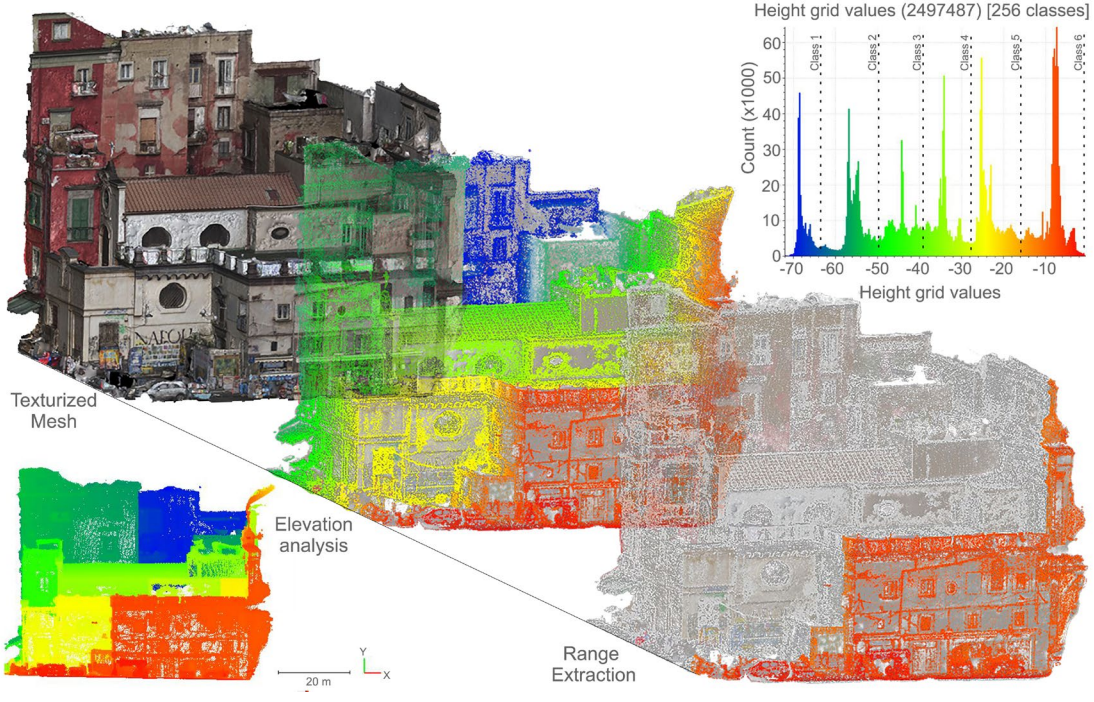
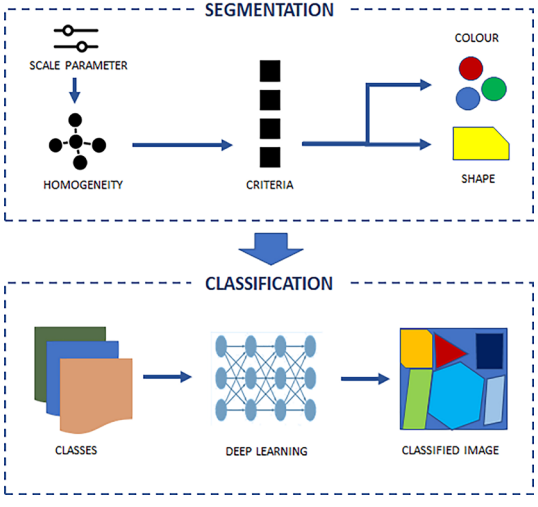


Fig. 11 - Outcome of the discretization and classification process of building curtains by depth levels of the digital model.

Fig. 12 - Multiresolution segmentation and supervised image classification process.



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remained or changed over time. However, the obtained results have shown some issues and open challenges, which are worth mentioning. First, the framework has provided slightly worse results than for the molding classes. This result was somehow predictable, as this class has high form variability, influenced by the probability diagrams of the definition of the elements. The reliability of the aerial photogrammetric is hence crucial, and is often integrated with terrestrial photogrammetry, to achieve a high-quality raster data set for the distinction of a higher number of pixels per square unit in the analysis of the segmentation and classification of the parts of the building.
The future perspectives of this experience are open toward the optimization of these procedures, for the extraction of a data abacus, subdivided by component typology. This will produce the first level of connection between data acquired from surveys and the formal identification model, in HBIM as well [Apollonio, Gaiani, Sun, 2012, pp. 41-62; Bianchini et. al. 2017, pp. 67-90]. It will represent an inventory, articulated into various degrees of abstraction and data detail for each of the single components, according to the dimensional sensitivity required for its assessment, aiming to support the management and monitoring of the built environment [Quattrini et al. 2017].

CONCLUSIONS AND FUTURE DEVELOPMENTS

The architectural and urban complexity of the historic centers, in particular for the context of Naples characterized by a high heterogeneity of the parts that constitute its essence, makes it essential to experiment with new critical approaches to interrelationships, which increase knowledge and dissemination.
From the analyzed urban documentary and cartographic fragments, progressively detailed by the digital aerial and terrestrial survey, derives a reinterpretation of the building curtains that makes its own the tools of semantic segmentation, for the discretization of data and the automatic identification of architectural elements, recognizable both by shape and by type. This has favored the reconstruction and multiscalar digital representation of the construction phases allowing to offer a visible testimony of urban developments and transformations. In fact, despite the well-known complexity and uniqueness of the architectural elements, the digital models have made it possible to generate synthetic data that can be exploited to optimize the modeling process of the urban aggregate, also from an H-Bim perspective, and to systematize the signs of the transformations that have taken place over time. These traces are detectable, in the digital space, both on a large and small scale and the analysis cannot disregard an overall reading, in which the fragment of investigation facilitates the recognition of the evolutionary and perceptive dynamics, for which the entire urban structure can find in its fragment a powerful synthesis acting as a working paradigm for the other similar cases contained within the foundation square of the ancient Neapolis. This multidisciplinary and technological vision of heritage protection aims to be the digital key tool in current efforts to conserve, study and promote Cultural Heritage [Barba et al., 2020, p. 38].

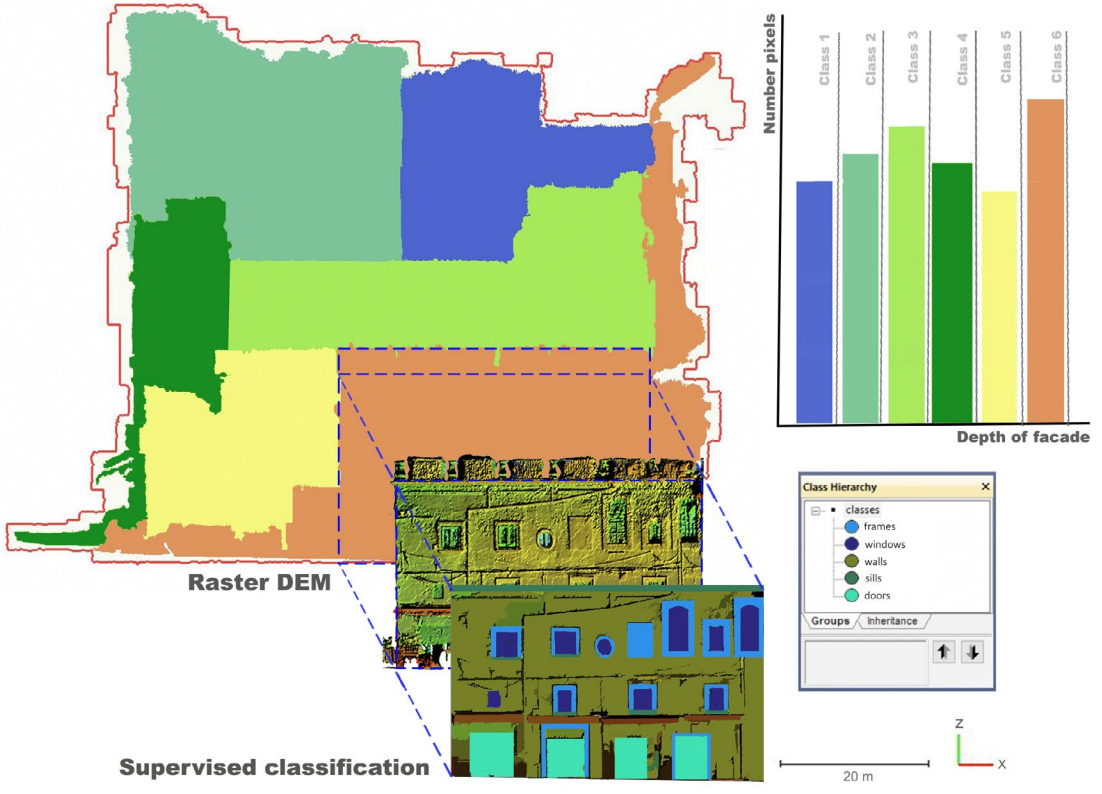

Fig. 13 - Outcome of the segmentation and classification process of one of the elevations of the urban area.

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NOTE

[1] The contribution is the result of the joint research work of the authors, as part of the activities of the RemLab (Survey and Modeling Laboratory), of the Department of Civil, Building and Environmental Engineering of the Federico II University of Naples. In particular M. I. Pascariello is the author of the paragraphs "introduction" e "New morphological notes about ancient center of Naples"; S. D'Auria is the author of paragraph "Survey and new visualizations"; G. Antuono is the author of the paragraphs "Semantic segmentation for the discretization of the urban scene" and "Conclusions and future developments". The graphic elaborations 1, 2, 3 e 4 were made by M. I. Pascariello, the 5, 6, 7, 8 e 9 by S. D'Auria, the 10 e 13 by G. Antuono, while the 11 e 12 by T. E. Martínez Chao, supporting digital survey activities, data integration and segmentation approach.

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