Digital Representation Platform and Multi-Scale Representation for a Multidisciplinary Knowledge of Some UNESCO World Heritage Sites in Italy

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ABSTRACT

The paper describes reading criteria for the interpretation/documentation, integrated systems of digital technologies and 2D/3D digitization of Cultural Heritage (CH) and the procedures followed by Digital Representation Platform (DRP) promotes through integrated digital survey for CH in Milan and Trento as a case study of the research on the integration of new technologies to obtain 3D multi-scale representation architectures. The study from the methodological point of view has made use of the identification of levels of study differentiated, each of which is capable of identifying categories.

Author Keywords

Digital Representation Platform, Multi-Scale Representations, 3DCM, 3D Digitization Methodologies, Heritage Recording

1. INTRODUCTION AND OBJECTIVES

In recent years, digital heritage has begun to transform the process of re-creating and understanding the past [1]. Infact, the purpose of the ICOMOS Charter for Interpretation and Presentation of CH Sites is to define the basic principles of Interpretation and Presentation as essential components of heritage conservation efforts and as a means of enhancing public appreciation and understanding of CH sites [2]. The paper describes reading criteria for the interpretation/documentation, integrated systems of digital technologies and 2D/3D digitization of CH and the procedures followed by DRP [3] through integrated digital survey. The DRP is meant to be particularly useful to heritage managers who are developing recording, documentation, and information management strategies for territories, sites, monuments. Recording, documentation, and information management are among the central activities of the decision-making process for heritage conservation management [4]. Conservation, being an ongoing activity, can be best described as a cyclical process, with heritage information being the knowledge base to which everyone dealing with the heritage contributes and from which everyone retrieves information. Without such a knowledge base collecting and disseminating information at all stages, the conservation process is without reference [5]. The DRP offer the possibility of obtaining new products not only in the surveying activity but also in representation, visualization, digital information and communications technologies with powerful instruments for multi-faceted analysis. Additionally, it offers a wide range of applications for collecting and processing historical data, monitoring of monuments and creating interactive information networks. Moreover, the present research project it is placed between the targets to explore the possibility of integrated digital survey and multi-scale representation. I have made 3D models of both the current status (geometric model) that support the analysis of the various stakeholders in order to identify guidelines for the relief aimed at the realization of multi-scale models of architectural sites. Today new opportunities for an integrated management of data are given by multi-resolution models, that can be employed for different scale of representation. It was identified a methodology for reading that can return a survey aimed at evaluating changes induced by simultaneity through the decomposition of multi-scale representation of the parties examined. Here I report the results of the research on most significant architectural buildings of Milan and Trento.

2. LINE OF RESEARCH METHODOLOGY

I identified relief guidelines aimed at the realization of architectural sites multi-scale models. This was made possible by the geo-referencing process consisting in the insertion of local systems in less local systems. Therefore the relation between the uncertainty of the model (derived from the uncertainty of the measurements), and simplification of the model (derived from selecting and transmitting only some geometric information considered essential to the description of the object on a certain scale) has been taken into account. The research was articulated according to the DRP of the architectural and the urban landscape, consisting of a set of cultural, geometric, morphological and dimensional knowledge for the creation of a 3D digital model implementable with multidisciplinary themes. The DRP improves current policies and standards and is based by: 1- heritage information with integrated activities of recording, documentation, and information management to acquire knowledge, understand values, promote the interest and involvement of scholars and ensure long-term maintenance and conservation of heritage places. 2- Information management with the process of finding, cataloguing and sharing information by making it accessible to potential users now and in the future; 3- Recording with the acquisition of new information deriving from all activities on a heritage asset, including heritage recording, research and investigation, conservation, use and management, and maintenance and monitoring. (Fig.1) The benefits of integrated digital survey describing the physical configuration of sites and their physical condition at known points in time fall into two broad areas: 1-conservation planning and management; 2-provision of a permanent archival record. These were the steps followed: 1- Visual frameworks in the urban space; 2- Criteria of heritage significance and principles of evaluation of CH assets. 3- Study of current methods of 2D/3D digitization intended and Open Source for CH preservation. 4- Study of the relief procedures with integrated laser scanning and photogrammetry. About the relief of the elevated parts, scanning and relief stance optimization were considered. 5- Study of the relief integration methods applied to the plan and the elevated parts in order to define a one-3D system. This was to identify the invariant with respect to the scale of representation in the geometry of the object and then proceed to the geo-referencing. 6- Study of best practices for the realization of 3D models that are mapped to different nominal scales and with different levels of detail. 7- Study of scale changes in the individual models (site, architecture, details) with simplifications based on the selection and activation of geometric information from different nominal scales. 8- Accurate documentation of each cultural object, encouraging an integrated interdisciplinary approach. 8- Study of Open Source tools and software for CH fruition and conservation. From a methodological perspective, the identification of Levels of Study (LS) has allowed me to identify categories of dimensional, constructive, formal and cultural values. Therefore, I started from the existing data collection organized by categories and subcategories, to understand the current relationship between identity signs and contemporary signs. The relief and the representation of the LS return information classifiable in a uniformed manner from a spatial, a functional, and a thematic point of view. The guidelines on criteria and conditions for evaluation of CH Assets were following: 1- historic and aesthetic significance. Is related to its style, technical excellence, beauty, quality of design and execution; 2- Scientific or research significance; 3- Social and spiritual significance. For this reason, the survey also was based on the following criteria for complex representation: 1-Intrinsic significance (Authenticity, Extent/Completeness, Integrity, Continuity of use/demonstration, Corpus of evidence/study; 2 - Contextual significance (Rarity, Representativeness /Uniqueness, Diversity, Physical context, Threat/fragility; 3- Associative significance (Historic interest and association, Aesthetic attributes. The principles of evaluation of CH assets is carried out in accordance with: 1- Scientific knowledge and experience in the field to which the cultural asset belongs; 2-Available data and documentation on the asset (inventory, survey, study); 3- Results of additional research specifically;

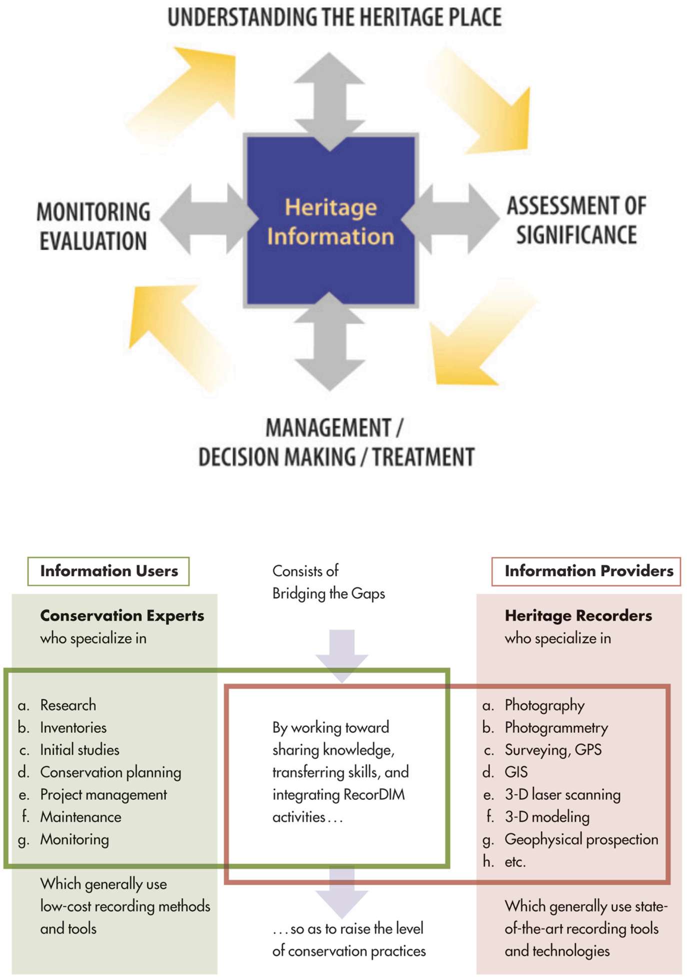


Figure 1: The use and flow of heritage information and Heritage Recorders (Brizard, Derde, Silberman, 2007, Basic Guidelines for Cultural Heritage).

connection/relation with other categories of asset, or persons, communities and regions [6].

3. MODEL AND CHARACTERISTICS OF MULTI-SCALE REPRESENTATIONS

The goal of multi-scale representations is to provide several representations where each representation is adapted to a different information density. Moreover, the multi-scale representations are representations of a given model in several degrees of detail [7]. Typically one primary representation is used to derive secondary representations with adapted scale as needed. In practice multiple discrete representations are typically prepared and stored in advance. An important characteristic of multi-scale representation is the similarity between the representations and the described subject, where similarity is defined depending on the purpose. According to defined by the Object Management Group (OMG), a model captures a view of a system and describes those aspects of the system at the appropriate level of detail. Ideally the required variant can be generated on-the-fly for a continuous range of resolution requirements. To overcome the problem of mismatch between required and prepared representation, the representation with the closest resolution is used. In their simplest form, multi-scale representations form a ordered, linear sequence of representations R0,R1, ...,Rn, where R0 has the highest detail and Rn the lowest. Frequently, multi-scale representations are organized hierarchically. Preprocessing a primary representation in a hierarchical way allows one to follow a divide-and-conquer approach, i.e., to split the problem into smaller portions and process them independently [8]. In 3D computer graphics, level of detail (LOD) modeling represents a fundamental principle LOD modeling enables interactive rendering of data sets that otherwise could not be rendered interactively or could not be rendered at all, as their size exceeds main or graphics memory, or processing power is too low. The LOD models are models with low polygon count either created by hand or derived automatically from a primary model [9]**.** To avoid disturbing popping artifacts when switching, geomorph techniques perform a smooth geometric interpolation between different LOD models [10].

3.1. From knowledge to Complex Representation: Multi-Scale Representations of Virtual 3D City Models for CH and Urban Space

According to defined by the international CityGML standard (see you Open Geospatial Consortium) a virtual 3DCM is the digital representation of urban space that describes geometrical, topological and appearance properties of its components with an explicit level of detail (LOD). In general, a 3DCM serves as an integration platform for multiple facets of an urban information space. Visualization is an important part of many applications of 3DCMs [11]. CityGML defines for city objects five LODs and requires that geometric and thematic aspects of a city object are described in context of one of the LODs [12]. (Fig. 2)

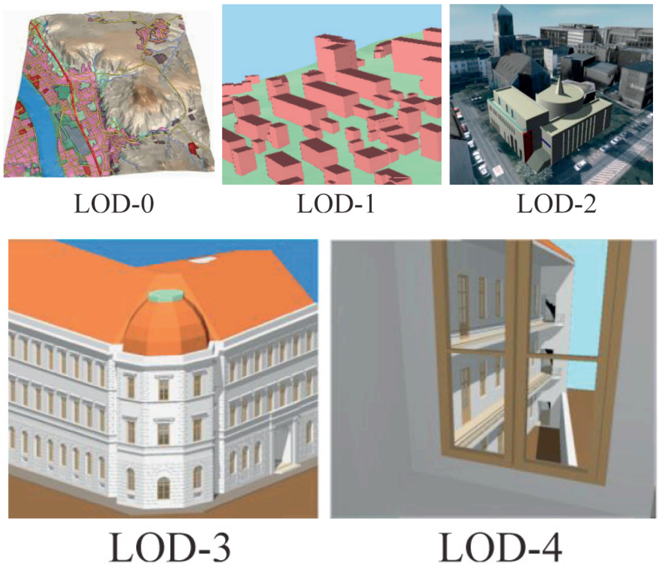


Figure 2: The CityGML specification contains these examples to illustrate typical use of its five consecutive levels of detail - LOD - (Gröger et al., 2008).

These were the LODs followed: 1- LOD-0 used for regional scale and contains a 2.5D terrain model with a surface texture applied. 2- LOD-1 contains prismatic block building models with flat roofs and no façade textures. 3- LOD-2 contains buildings with differentiated roofs as well as thematically and geometrically differentiated surfaces, including textures. Vegetation objects may be included. 4- LOD-3 contains highly detailed architectural buildings with high resolution textures as well as highly detailed vegetation and transportation objects. 4- LOD-4 adds interior structures to buildings, such as stairs or furnitures [13]. The CityGML standard is flexible with multiple representations of a 3DCM. Infact, 3DCM should be used: 1- Combinations of different LOD representations of buildings and the relief model within the same scene is possible. 2- CityGML introduces the concept of the terrain intersection curve (TIC), which describes the interface between a feature. It is a applications can locally adapt the terrain model to embed the feature. According to defined by Kada (2005) suggests reconstruction of a building model using half spaces. For each wall face of the original model, the algorithm creates a plane and a related buffer. Starting with the face with the largest area, the algorithm merges faces within a given maximum distance to the current face's buffer, adapting the plane's parameters and leading to a smaller number of planes. The final set of planes is used to create a cell decomposition of the building. Rau et al. (2006), suggests an approach working on building models comprised of prismatic shapes with sloped roof structures. First, the roofs are flattened and adjacent polyhedrons are merged if their height difference is smaller than a given feature resolution, yielding 2.5D shapes. Moreover, Forberg

(2004) introduces another scale-space based on parallelism to generalize earlier findings and combine characteristics of both morphological and curvature space operations. The algorithm identifies parallel faces of the model and, starting with the smallest distance, moves faces towards each other so that they share the same plane. The moved faces result in merging building parts, removal of protrusions or adjustment [14]. In the approach of Fan et al. (2009) is directed at generalizing CityGML LOD-3 building models where the polygons belonging to one wall are projected to the farthest of its polygons' planes; polygons that are not parallel or coplanar are discarded. In his thesis Fan (2010) suggests another approach for the computation of CityGML LOD-2 building models with the building footprint is simplified using rules from Staufenbiel (1973), extended by rules to handle non-orthogonal curvature. Moreover. the roof geometry is generalized by individual polygons that are simplified using the same rules. Third, the generalized footprint is extruded until it meets the generalized roof geometry. Coors (2001) applies an adapted surface simplification algorithm (Garland and Heckbert, 1997) to simplify single buildings. Introducing dominance values on important parts of the building. The simplification algorithm is adapted to conserve these parts while simplifying geometric complexity of the remaining model [15].

3.1.1 Cell-Based Generalization

Cell-based generalization another technique to create representations of 3DCMs that are focused on giving a quick overview about the general structures of the urban space and is intended to facilitate multiple purposes. According to defined by Lynch (1960), who describes five major elements forming a city's mental image: paths, edges, districts, nodes, and landmarks distinguishable objects used for orientation. Therefore, I address this by using street network, coast lines, as well as non-building areas of a 3DCM to create cell blocks. I assume that block cells can represent individual buildings and monuments abstractly. The cell blocks are further shaped by computational geometry operations and enhanced by landmark buildings, which are maintained in the visualization. 3D building shapes are included, rendered as transparent shapes and with perspective projection in real-time. The visualization aims at adaptation to the scale: with increasing scale, buildings are first represented as footprints, then as oblique 3D shapes with reduced height, then with their full height. Secondly, photo-realistic perspective views of 3DCMs – either real-time renderings or oblique photographic imagery – are enhanced with text, icons, and rendered vector data [16]. (Fig. 3) The technique of Royan et al. (2005) processes 3DCMs containing 2.5D building models to get a hierarchical representation usable for progressive transmission. The algorithm applies simplification operations to the 3DCM: footprint simplification by vertex removal, aggregation of adjacent buildings by edge removal, and aggregation of non-connected buildings guided by a cost function [17]. Designing landmarks in virtual 3D environments such as 3DCMs therefore can facilitate navigation and the acquisition of spatial knowledge [18]. Local landmarks and different levels of global landmarks can be differentiated by the size of their reference region. For higher LOA representations, I use a different technique to identify landmarks. The goal is to reduce the number of landmarks, while keeping important ones and maintaining an even spatial distribution. In the resulting landmark hierarchy, the number of landmark buildings is steadily reduced in subsequent layers of the hierarchy. (Fig. 4)

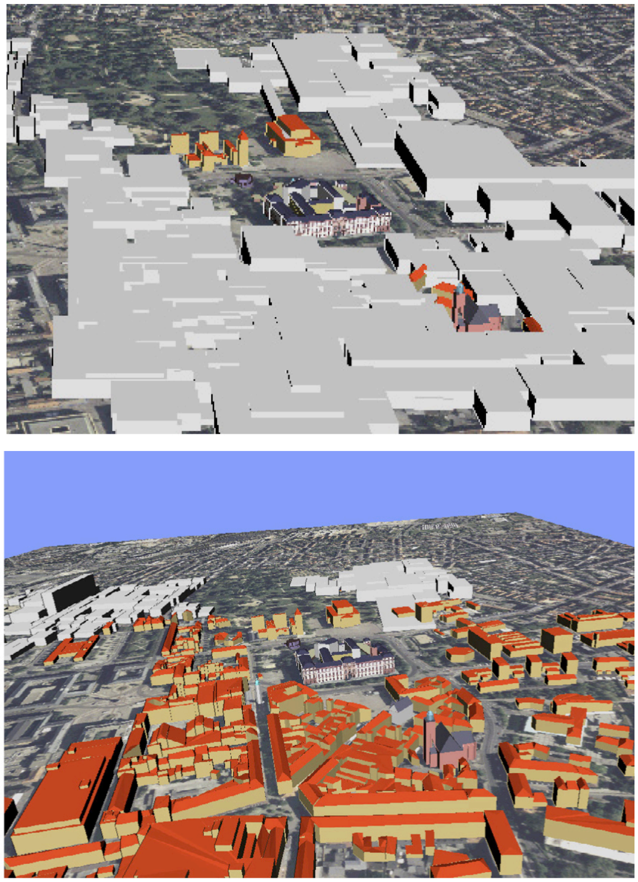
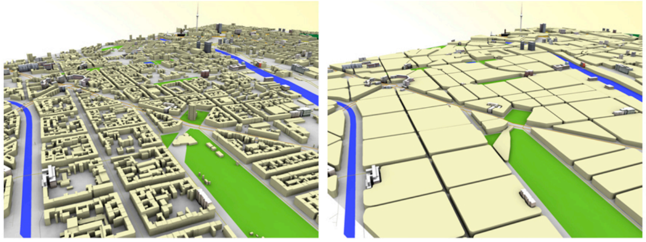


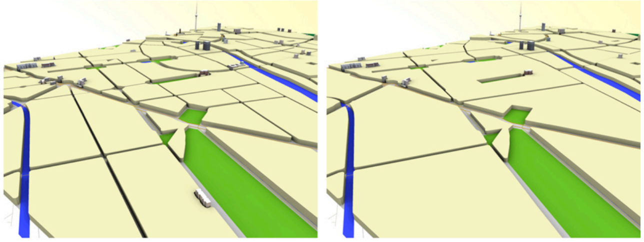
Figure 3: Buildings models are aggregated using boxes stored in an R-tree for efficient network transfer and visualization. Landmark buildings such as churches can be presented with a higher detail using dominance values (Coors, 2003).

3.1.2 Creating Building Representations

We have two types of building representations: high detail 3D geometry stored for single landmark buildings and 2.5D cell blocks. Whilst the former is directly integrated into the scene, the latter requires the creation of 3D geometry by extruding their polygonal footprints. The extrusion shape consists of wall geometry and planar roof geometry. We use



(a) LOA^0 (b) LOA^1



(c) LOA^3 (d) LOA^4

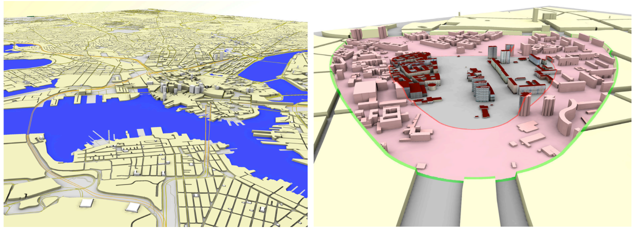


Figure 4: For increasingly abstract representations, the algorithm creates increasingly large block cells with decreasing numbers of landmark buildings (small Berlin dataset). The definitive version of these images can be found at (Glander and Döllner, 2009).

the computed LOA representations in a focus+context scenario by applying generalization lenses [19]. (Fig. 5)

4. 3D DIGITIZATION METHODOLOGIES

At present there is a significant variety of 3D acquisition methodologies. Those can be classified to contact and noncontact 3D scanners [20]. Contact systems are not popular in the CH domain due to the fragile nature of artefacts. In contrast, non-contact systems have been used during the last decade in many CH digitization project with success [21]. Non-contact systems are divided into active and passive. The Laser Triangulation (LT) active acquisition method is based on a system with a laser source and an optical detector with the depth is computed by using the triangulation principle. The acquisition system is able to capture both geometry and colour using the same composite laser beam while being unaffected by both ambient light and shadows [22]. The Time-Of-Flight (TOF) active method is used for the 3D digitization of architectural ensembles. The method relies on a laser range finder which is used to detect the distance of a surface by timing the round-trip time of a light pulse [23]. For large measuring ranges TOF systems provide excellent results [24]. The Structured Light (SL) is another popular active method that is based on projecting a sequence of different density bidimensional patterns of non-coherent light on the surface of an object and extracting the 3D geometry by monitoring the deformations of each pattern [25]. The SL systems that are able to capture 3D surfaces in real-time by increasing the speed of projection patterns and capturing algorithms [26]. The Image-Based methods involve stereo calibration, feature extraction, feature correspondence analysis and depth computation based on corresponding points can be considered as the passive version of SL. Photogrammetry is another popular active method that is used to determine the 2D and 3D geometric properties. It can be described as the determination of camera interior and exterior orientation parameters, as well as the determination of the 3D coordinates of points on the content of the images [27]. Open photogrammetric software solutions are able to perform tasks such as high accuracy measurements, camera epipolar geometry computations and textured map 3D mesh extraction. Recently have been introduced semi-automated image-based methods such as Structure-From-Motion (SFM) and Dense Multi-View 3D Reconstruction (DMVR) methods. The SFM-DMVR (algorithms from unordered image collections) attempts to reconstruct depth from a number of unordered images that depict a static scene or an object from arbitrary viewpoints. The method mainly uses the corresponding features, which are shared between different images that depict overlapping areas, to calculate the intrinsic and extrinsic parameters of the camera [28]. Eos Systems Inc. offers PhotoModeler Scanner software to perform tasks such as reconstruct the content of an image collection in 3D dense point cloud that can be converted to a triangulated 3D mesh of different densities. In the same direction, Agisoft offers PhotoScan to perform high quality 3D reconstructions, orthophotographs, digital elevation models and georeferenced 3D models.

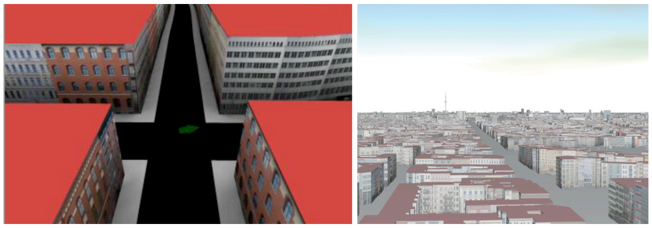


Figure 5: Schematic and 3D example of a junction after (right) processing of road segments, landmark buildings can be emphasized by scaling them according to their importance for navigation and orientation, enhancing the skyline.

4.1 Case Studies: Digization of Cultural Heritage

The cases study are a attempt for the 3D digitization and representation of two CH in Milan, Italy. There are no buildings around the monuments and they are considered an open access monuments. The 3D digitization of the monuments could be performed using photogrammetric survey with multi-image 3D reconstruction. The position of the two monuments allow the selection of viewpoints for photoshooting around the model. I used Agisoft PhotoScan as software solution for the production of digital 3D replicas of monuments. Infact, the process of capturing require temporary scaffolding for the image-based methodologies. I need to create a complete exterior 3D model of a monument using terrestrial photography. Moreover, I compare the 3D mesh produced by the SFM-DMVR software against the data I captured using terrestrial 3D laser scanning and total station surveying. For the terrestrial photo shooting session a DSLR Nikon D40 (18-55 mm lens) has been used with distance of the camera from the monument's surface was estimated at 5 meters. The range scans covered both high and low curvature areas that were enough for validating the quality of the data produced by SFM-DMVR software [29]. A total of 400 photographs has been used for the 3D model of the monument 300 and a total of 24 points were measured using a Topcon GPT-3005N total station. The SFM-DMVR software (Version 0.8.5) has been used for this case study. (Fig. 6)

4.2 Heritage Recording and 3D Modeling with Photogrammetry and 3D Scanning

The aspects of the evolution of CH can be documented by the combined use of laser scanner and techniques of photo-scanning. (Fig. 7) In fact, the photogrammetry has had the task of providing the deliverables on which to base the reading multi-scale. Through geo-referencing, in the process of surveying, which can identify the invariant with respect to the different scales of representation in the geometry of the objects. The network classification of sites surveyed for buildings recorded in Milan was composed in two schemes. The network was built with total station Leica TCA, while the GPS and Leica GPS System 500 GPS1200. The points of support for the relief photogrammetric were detected with both topographic measurements (Leica TCR1103 and TCRM 1103) from ground GPS. The GPS survey was carried out with a long session for the determination of the absolute coordinates of the points of the main network, while for the determination of natural or target points for the support photogrammetric has acquired in RTK mode. The laser scanner used is the model of the Riegl LMS-Z360i with integrated digital camera which offers the opportunity to acquire not only the three points needed to determine the coordinates X, Y, Z each point but also to acquire even the RGB values corresponding to each measured point. To obtain a dense DEM models of the monuments of the site, you have done a total of 17 scans in overview mode and detailed in the in the center of Milan, and 13 in Trento, always in the two modes. The clouds were aligned on the basis of support points and tie points measured topographically distributed in the scanning area. The optimal value of 0.2 mm multiplied by the denominator of the ratio allows you to fix a priori a pattern of acquisitions in a manner very similar to the design of a photogrammetric survey, considering not only the overlap between scans to ensure good alignment, but also a distribution "pseudo-do-set" of points. The construction of a 3D-RGB digital model, obtained by some digital images of a real model, makes possible to acquire not only geometric

Figure 6: SS. Giovanni Battista e Paolo Church, Milan, Italy (architects Figini e Pollini). Image position around the Church and Reconstructed CH by Smooth Shaded Triangular Mesh and Vertex Painted Medium Quality Triangular Mesh.

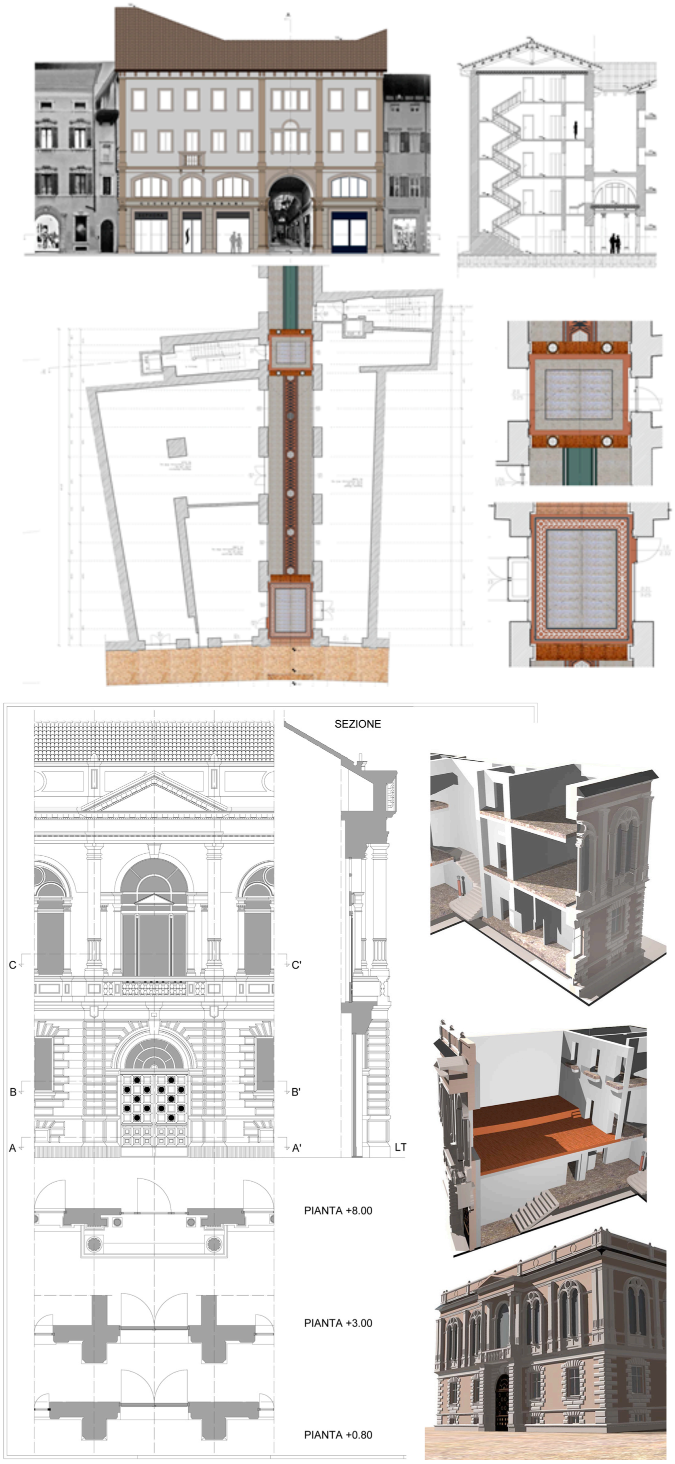


Figure 7: image 7- Galleria Garbari and Sala della Filarmonica Palace, Trento (Italy). Dimensional survey, architectural survey with the elaboration of plans and sections (scale 1:50 and 1:25). Milan, Italy. Course of Drawing, Milan Polytechnic (A. De Masi)

data but also chromatic and thematic data. The data acquisition phase with ZScan was obtained by simultaneous acquisition of point of clouds and "photo-scanning" textures based on an algorithm of tri-multifocal analysis of the image. The latter, using coloured point of clouds, sees the images as input of information being metrically and chromatically valid in 3D coordinates of the points. The resulting models were exported for the subsequent phases of editing and generation of plans, sections, profiles, contour lines, up to DEM (Digital Elevation Model). The use of multi-level images, obtained with overlapped colored filters, can return as a photometric light curve resulted from the amount of absorbed light.

5. RESULTS AND CONCLUSION

In this paper different approaches to the acquisition and visualisation of 3D information from images have been examined. Moreover in this paper different approaches to the 2D/3D digitisation, 3D data acquisition methodology, 3D data post-processing of 3D information from images have been examined. I have to demonstrate that 3D acquisition methodology play an important role at all scales of research. 3D modeling should be intended as the generation of structured 3D data from the surveyed unstructured data and it consists of geometric and appearance modeling. However, for large sites'3D modeling, the best solution is the integration of image and range data for document and preserve the landscape and heritage as well as share and manage them. The RDP is configured in this way as a resource to analyze the complex reality of measuring the material aspects with socio-economic mechanisms of perception of the quality of living. In addition the RDP show the potential of modern technologies of detecting, sharing and managing digital information in order to preserve the CH. The recent developments in image matching have demonstrated the potential of photogrammetry to derive all the fine details of an object with geometric results from a relatively small number of images very similar to active sensors.

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