Ruotsin suurvalta-ajan vesikattorakenteet Suomessa

Toimittaneet

Marko Huttunen, Laura Eerikäinen, Laura Laine, Pauliina Saarinen & Panu Savolainen

Senaatti

Museovirasto

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Kannen kuva
Louhisaaren kartanon päärakennuksen kattorakenteita.

Takakannen kuva
Uudenkaupungin vanhan kirkon kattorakenteita.

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SISÄLLYS

RAPORTIT

ARTICLES

Laser Scanning Surveys of Wooden Heritage and Timber Roof Structures and their Post-production. Methods for Detailed 2D and 3D Representations

Sara Porzilli

Abstract

This contribution aims to share research experiences related to wooden heritage located in different European and Mediterranean areas. Today this vast and unique wooden world heritage strongly needs to be surveyed and catalogued. The research experiences described below offer a wide viewpoint on how survey operations can be performed and the numerous outputs and benefits that can be achieved from this type of digital survey method. The evolution of new sophisticated techniques of detection can today overcome difficulties and be a useful addition to the everyday efforts we make in order to safeguard the condition and preservation of our built heritage.

Introduction

Laser scanning technology nowadays represents one of the most efficient type of survey for measuring and documenting wooden heritage and timber structures in general. Historic wooden architecture is characterised by complex constructive systems made of by unique pieces and detailed parts (for example corners and carved ornaments) which appear difficult to measure with a high accuracy using normal, simple measuring tools. Research activities[1] and specific studies[2] have confirmed that different cultures all over the world hold their own "chapters" of historic wooden architecture, different in its constructive systems and compositional results but also rich in common features. For this reason we can assume that wooden architecture represents one of the oldest building systems adopted all over the world by people who developed specific construction techniques while respecting local tradition. From a theoretical point of view, Vitruvius' concept of the "primitive hut"[3] as the origin of all of classical architecture has increased and enriched this topic with fascinating additional shades and aspects. Today wooden heritage is still present and exists in many different countries, but it is under constant risk of disappearing or being irremediably damaged if specific conservation strategies are not taken into account. Fires and abandonment are the main factors jeopardising the preservation of this specific architecture. Every year too many wooden buildings still disappear because of such events. For these main reasons today this vast and unique wooden world heritage strongly needs to be surveyed and catalogued, using the most recent and updated technologies available. During the past two years the History of Architecture and Restoration Studies Unit of the University of Oulu has been increasing knowledge and the

digital archive related on this topic along with the "Preserving Wooden Heritage" European Marie Skłodowska Curie Project. This project started out from the evident and urgent necessity to keep and *preserve wooden architecture by developing systematic specific technical intervention procedures based on scientific surveys*, including 2D/3D representations for diagnostic analysis and cataloguing of the elements with census activities. According to the preface of the *Conservation of Historic Timber Structures manual*[4] "There are no standard technical solutions which can be applied universally. Our experience is that repair approaches must be geared towards the specific cultural, architectural and environmental challenges in the country or region where the historic timber structure is located. With this background, one of our most important tasks [...] has been the development of the Principles for the Preservation of Historic Timber Structures". The PresWoodenHeritage Project has the important challenge and purpose of operating within the ICOMOS Principles for *defining new technical methods, procedures and protocols fundamental for technicians and operators involved in different types of activities*: restoration, documentation, re-assessment and re-designing necessities, re-use, accessibility projects and preservation needs. Alongside the technical and operational aspect, the experiences illustrated here have also involved a theoretical and academic approach for the advancement of the state of the art related to the new integrated digital survey systems for improving 2D and 3D post-production methods. There is a possibility of obtaining new and updated procedures for systematic analysis in respect of the Research-Theory-Practice triangular approach.

Four wooden case studies

This contribution describes four specific case studies located in different regions of the Mediterranean and Europe, as a demonstration of the wide presence of wooden heritage all over the world. The case studies are: the Lamminaho Farm House in Vaala region (Finland), the Pogost Complex on Kizhi Island with its rural settlements (Republic Of Karelia – Russia),[5] the timber trusses and wooden ceiling at the Uffizi Museum (Firenze – Italy) and the ancient roof structure of the Nativity Church in Bethlehem (Palestine). Even if these cases are noticeably different from each other in terms of the nature of the object investigated and its location, they have all contributed to increasing knowledge and "technical consciousness" on how to conduct surveys and document wooden heritage (Figure 1).

The historic *Lamminaho Farm House* in Vaala region (Finland) preserves and documents the original features of a traditional historic wooden complex dating between the 18th and 19th centuries. Lamminaho represents a unique very well-preserved example of wooden heritage, a place where restoration and repair interventions have been undertaken respecting the genius loci,[6] by using traditional techniques so that the authenticity and spirit of the place have not been compromised. Today responsible experts[7] are promoting the idea of using this place as an open-air museum which is an authentic testimony of a real Finnish farm house. For this reason, the National Board of Antiquities and Senate Properties have commissioned an important survey not only of the architecture but also of the whole environmental area in order to gain a complete framework of the actual situation of the place. The main aim has been to set up a documentary corpus for supporting all the different technical actions. This project

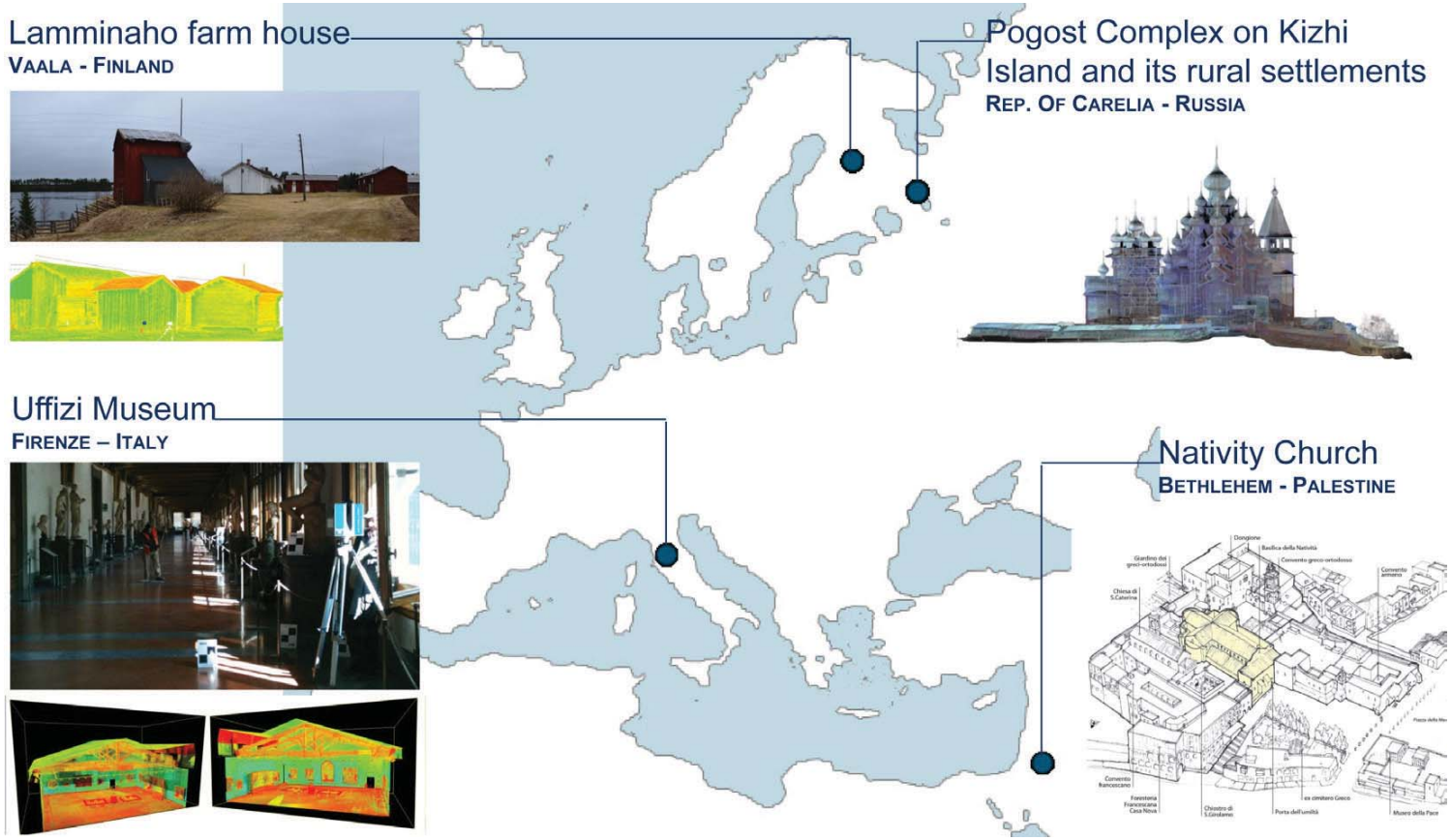


Fig. 1 Location of the four case studies.

has contributed to increasing the important practical strategies for carrying out laser scanning surveys of wide areas, taking measurements of both the environment and the architecture.

The second case study, the *Pogost Complex* and the rural settlements on *Kizhi Island*, has made a precious contribution to understanding how to handle a wide amount of data, and how to represent wooden historic structures in 2D and 3D for technological assessment analysis. The complexity of the architecture of the Church of the Transfiguration and the presence of a dense metallic structure supporting the wooden ones transformed this survey into an interesting and challenging experience.[8]

The third case study is located in Italy at the historic *Uffizi Museum*. The project has been part of a wider research project carried out from 2010 by the Department of Architecture DIDA in Firenze jointly with the Civil Engineering and Architecture Department DICAr of Pavia.[9] The reason for these activities has been the need for the museum managers to enlarge the

museum spaces and develop detailed monitoring analysis for specific wooden structures. In this case, the timber trusses in the Botticelli Room and the timber ceiling above the Lorenese Staircases (Firenze – Italy) are shown. Thanks to these cases it has been possible to develop interesting methods for monitoring structures subjected to specific consolidation work during long periods in order to obtain metrical information related to their consequential assessments.

The last case study is represented by the unique example of the roof structure of the *Nativity Church* in Bethlehem. The survey project[10] requested by Piacenti s.p.a., responsible for the restoration of the whole architectural complex, has been an important opportunity to document this precious timber roof structure and conduct some experiments using the newest photo-modelling software.

Research approach and development of the survey activities

All four research cases presented here arose from the idea that accurate surveying operations nowadays constitute the fundamental basis for designing any kind of architectural project and critical analysis. Innovative methods for surveying architecture and its environment allow technicians to acquire exact knowledge of the current status of the object studied and give exact information to produce effective intervention strategies. True metrical information and data are fundamental to understanding the formation and development of an architectural entity, village, or city, as well as for planning

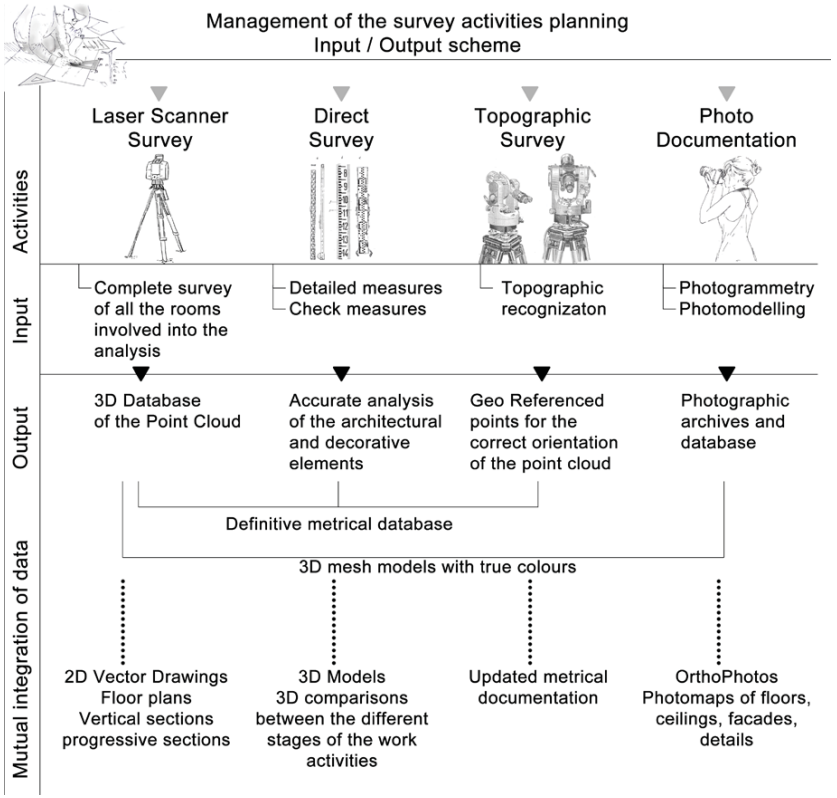


Fig. 2 Integrated research work needs detailed organisation of the different activities carried out. Using schemes and diagrams it is possible to handle and understand suitable solutions for achieving the best results from each work operation

conservation and restoration projects starting from the present state of a building. In order to get the maximum information from a survey campaign, an integrated[11] research project requires detailed organisation of the different activities carried out combined with an indicative time line. Using schemes and diagrams, it is possible to develop suitable solutions for achieving the best results from each operation (Figure 2). In addition to a laser scanner survey, general and detailed photo documentation, a direct recognition of the main measurements by using simple tools and often preceding archive research are undertaken, too. For the Lamminaho and Uffizi Projects it was necessary, for example, to fix exact time schedules to coordinate and fix periodic monitoring scans in order to obtain the most relevant data comparisons. This information then constituted the overlaying data documents.

In order to obtain a precise combination of the different survey phases it is necessary to use the same target system.[12] For this reason it is important to understand in advance if a survey project needs this kind of operation, because it will be necessary to keep the same targets strongly fixed in their positions during the whole period of survey activity.

Again during the preliminary phase it is important to list which types of data need to be obtained. Analysis and survey activities produce a large volume of updated documentation, characterised by different types of data, including:

- Metric databases (point clouds) obtained from laser scanner survey
- Photo Documentation for general observations, for photo-mapping of facades and sections, for photo-modelling operations
- Vector bidimensional drawings obtained from the elaboration of the point clouds, in particular: general plans, vertical and horizontal sections, progressive sections, comparisons of data obtained during different detection phases with dimensioning of height differences
- Three-dimensional models (for the specific case of the Uffizi Museum) obtained through the elaboration of the point clouds, overlapping the different steps to understand the minimum movements of the structures and conduct static assessment of floors, vaults and wooden structures

For the Lamminaho project two different types of laser scanner and software were used and tested (the first campaign in 2015 was performed with a Leica GeoSystem and the second in 2017 performed with a Zoller + Fröhlich laser scanner) (Figure 3). This possibility offered interesting comparisons of the data acquired and better understanding of different procedures. During the second campaign a massive project was developed in addition to the first one, by making more than 90 scans in order to survey all the external and inner parts in detail. These scans were registered with Z+F Laser Control Software which allows one to see all the scans from a top view mode directly on the map generated and gives you the possibility to recognise each singular scan position and navigate within it (with a double click on the blue sphere).

The fruitful synergy between technicians and experts from the university and partner companies[13] added value to the research experiences, increasing our positive results. The most complex aspect of this research has been the ability to perform a laser scanner survey which described all the architectural

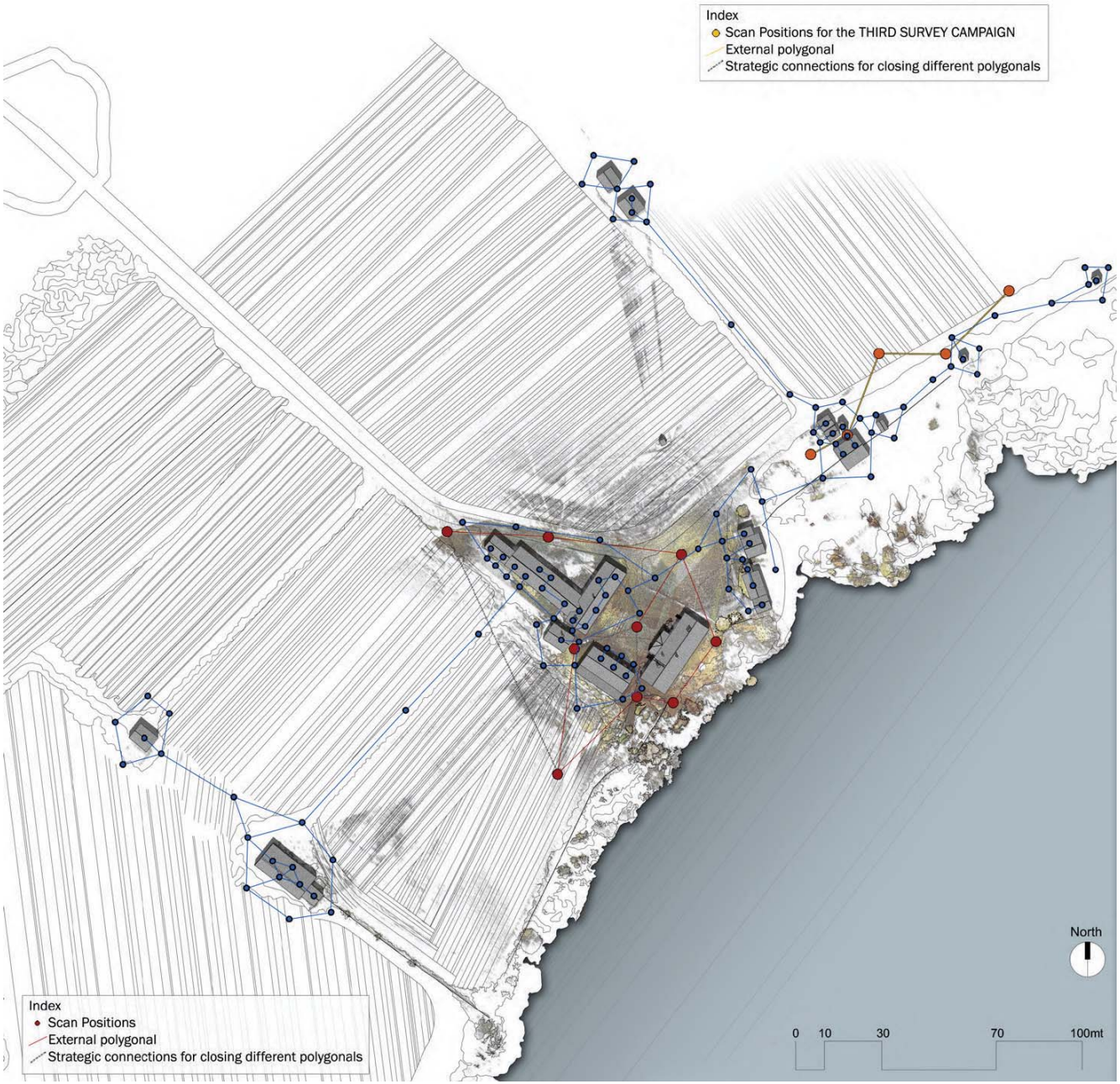
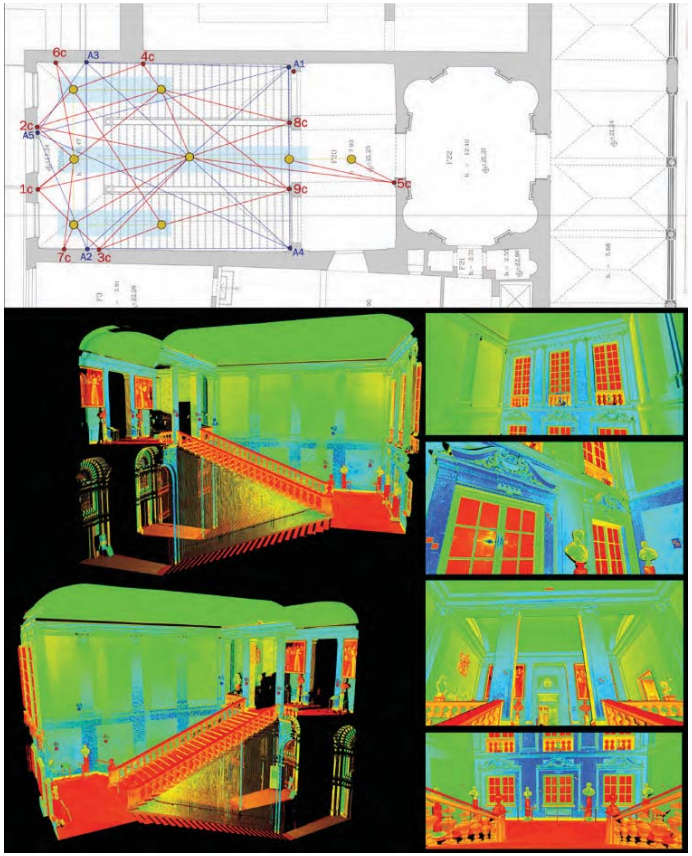


Fig. 3 Representation of the scan positions. The first survey campaign (2015) is shown in red, the second campaign (2016) in yellow and the third campaign (2017) in blue.



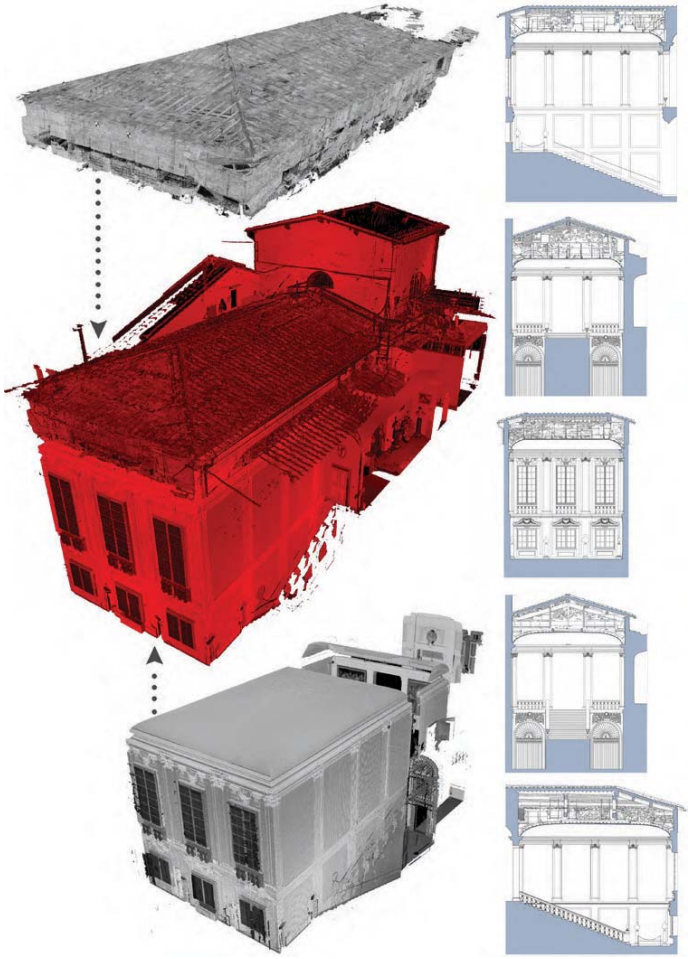


Fig. 4-5 Reference system with fixed targets for the registration of point clouds. views of point clouds of the access staircase, the survey was conducted for the study of the vault.

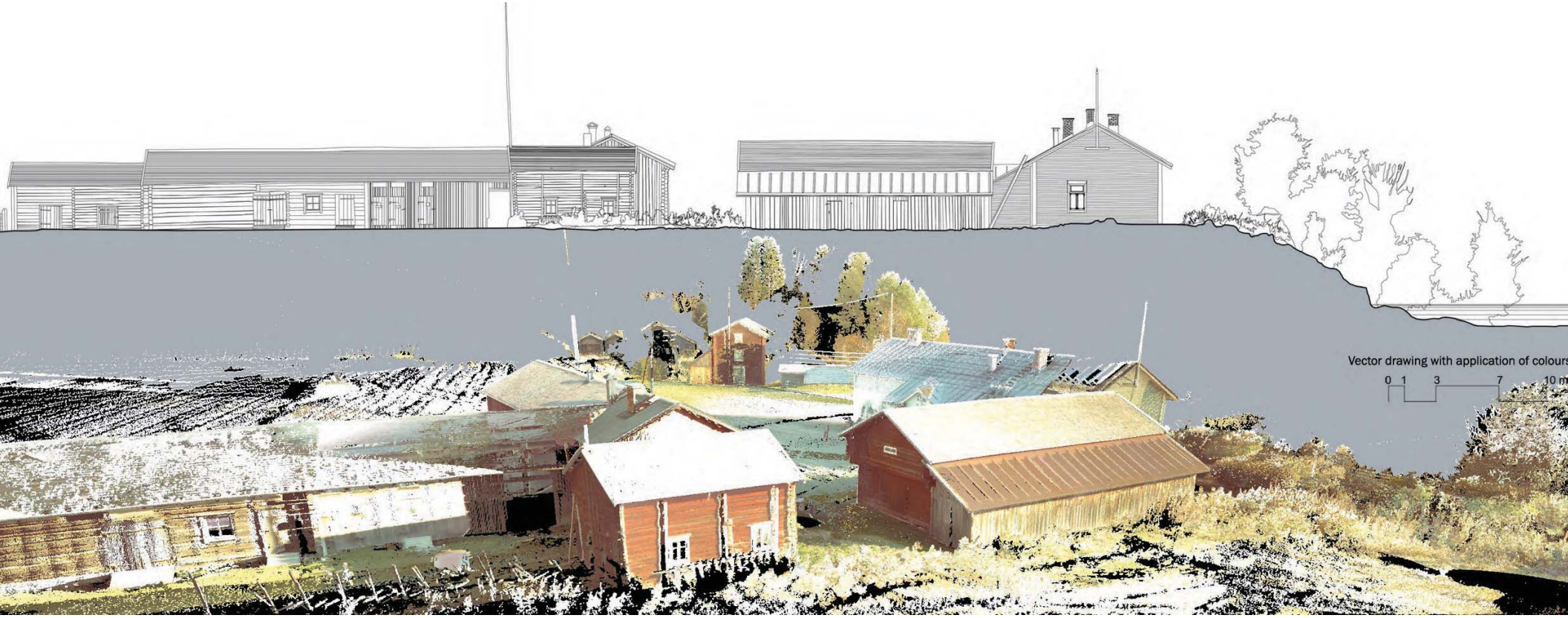


Fig. 6 General view of the point cloud of Lamminaho and an environmental section redrawn in AutoCAD software to get the real dimensions of the river bank and an understanding of the relations between the buildings.

structures completely, obtaining a full survey and investigation of all the necessary parts and surfaces. For the Lamminaho, Pogost Complex and Nativity Church projects, all the external and inner parts were surveyed in high and super-high resolution.[14] For the Uffizi project, the necessity to study both the external and internal parts of the wooden structures meant the survey campaign was enlarged into other areas and rooms not directly involved in the analysis but fundamental for elaborating the triangulation of the points and closing the polygonal paths. By closing the polygonals and using a system of scan positions it is possible to obtain more accurate results and achieve better compensation for geometrical error (Figures 4 and 5).

In order to reduce errors in the scans used to make the correct connections as much as possible, ultra-high resolution scans were conducted. For all four cases the precise organisation of the scan positions was defined in advance in order to set the practical activities and quantify the amount of work necessary in the field. This procedure is recommended because it gives

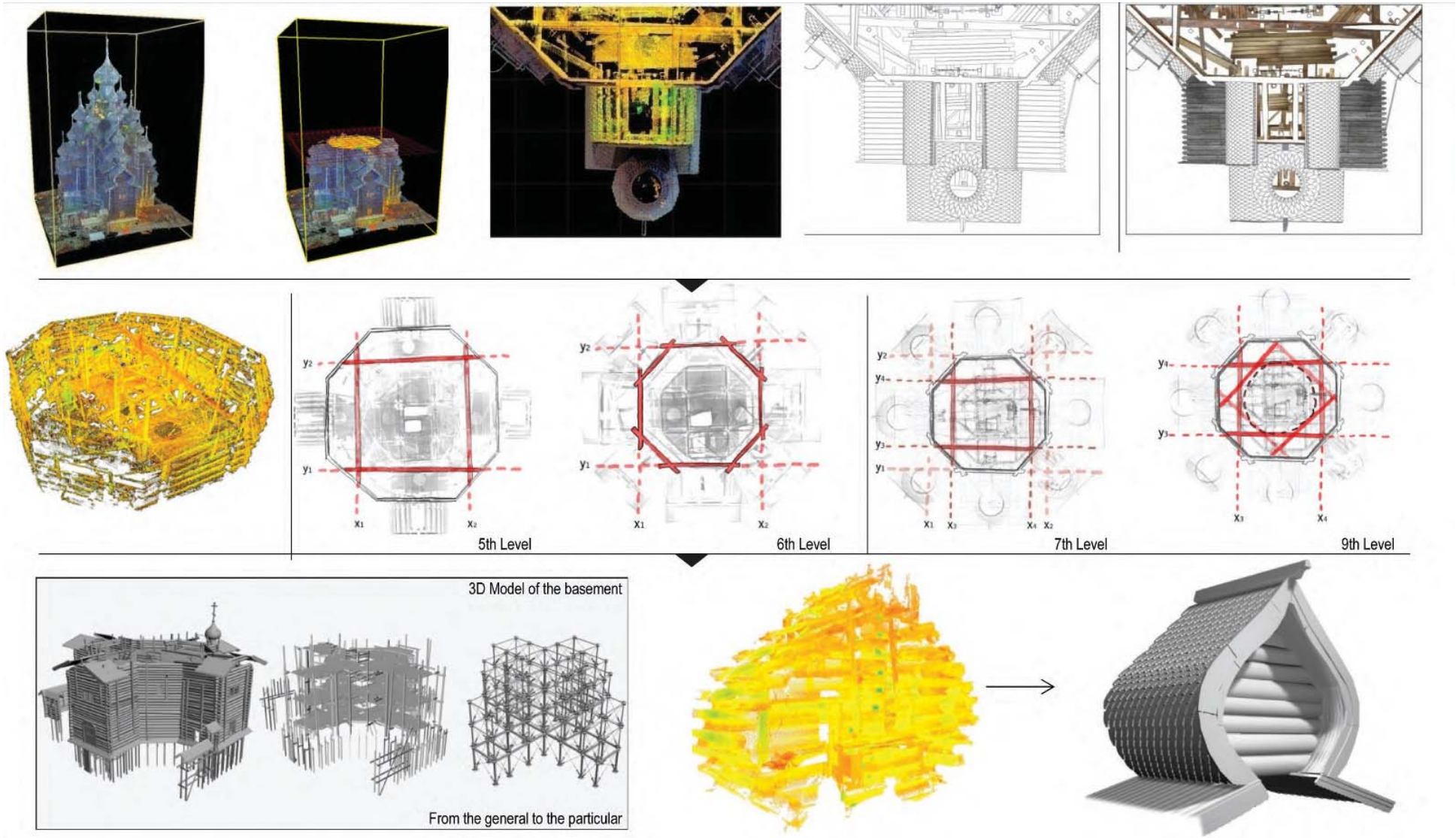


Fig. 7 General view of the data processing phase for the Church of the Transfiguration in Russia. The analysis started from the laser scanner survey. All the vector drawings were produced from the point cloud. From the vector drawings a 3D model of the basement and some specific parts were produced, for example the traditional vaults covered by scandols.

a real and practical understanding of the work and obligates the surveyor to elaborate in advance all the necessary work strategies useful for carrying out the research and obtaining the results. The organisation of the scan positions is generally determined by specific factors, for example:

- The presence of obstructions which obligate the surveyor to move the instruments into different positions in order to avoid the possibility of missing data
- The necessity to create the right connections between external and internal areas
- The necessity to survey the object investigated with the highest resolution, avoiding when possible shadows and holes in the point clouds (for example with the case of the ceiling structure in the Uffizi Museum and the timber roof structure of the Nativity Church).

Alongside the technical and operational aspects, all these experiences involved a theoretical and academic approach to the advancement of the new integrated digital survey systems. During these research experiences 2D and 3D post-production methods were improved in order to obtain the newest and most updated procedures for systematic analysis.

Post-production phase and representation of data

The most complex aspect of these research activities was the ability to perform a laser scanner survey which described all the architectural structures completely, obtaining a full survey and investigation of all the upper and lower parts of arches, external and inner parts, wooden details and ornaments of the timber structures. For each case study detailed 2D CAD drawings were produced, using different metric scales according to their purposes, as well as 3D models and/or simulations and photomaps to represent the architecture in its real aspect. It can be useful to summarise in detail the main purpose of each project and the technical materials produced:

Lamminaho Project: Documentation of the entire area in terms of both architectural and environmental aspects for preservation and restoration activities. Materials produced: elaboration of environmental sections (metric scale 1:50) for an updated recognition of the landscape; updated measures of the river bank area; analysis of the relations between buildings and open areas. For each building we produced: floor plans, technical drawings of the facades, longitudinal and/or transversal sections in 1:50 scale. Each façade has a real photomap elaborated in 1:20 metric scale (Figure 6).

Pogost Complex Project: Analysis and understanding of the architectural structure of the Church of the Transfiguration. Documentation of the island and its rural settlements for landscape analysis and for dissemination useful for touristic purposes. Material produced: Environmental sections in 1:50 scale, floor plans, longitudinal and transversal sections with a 1:5 scale of resolution, 3D model of the first octagonal basement and different tests of modelling straight from the point cloud information. Photomaps of each CAD drawing (plans, sections and facades) completed the documentation using photo documentation made up during the survey campaign (Figure 7).

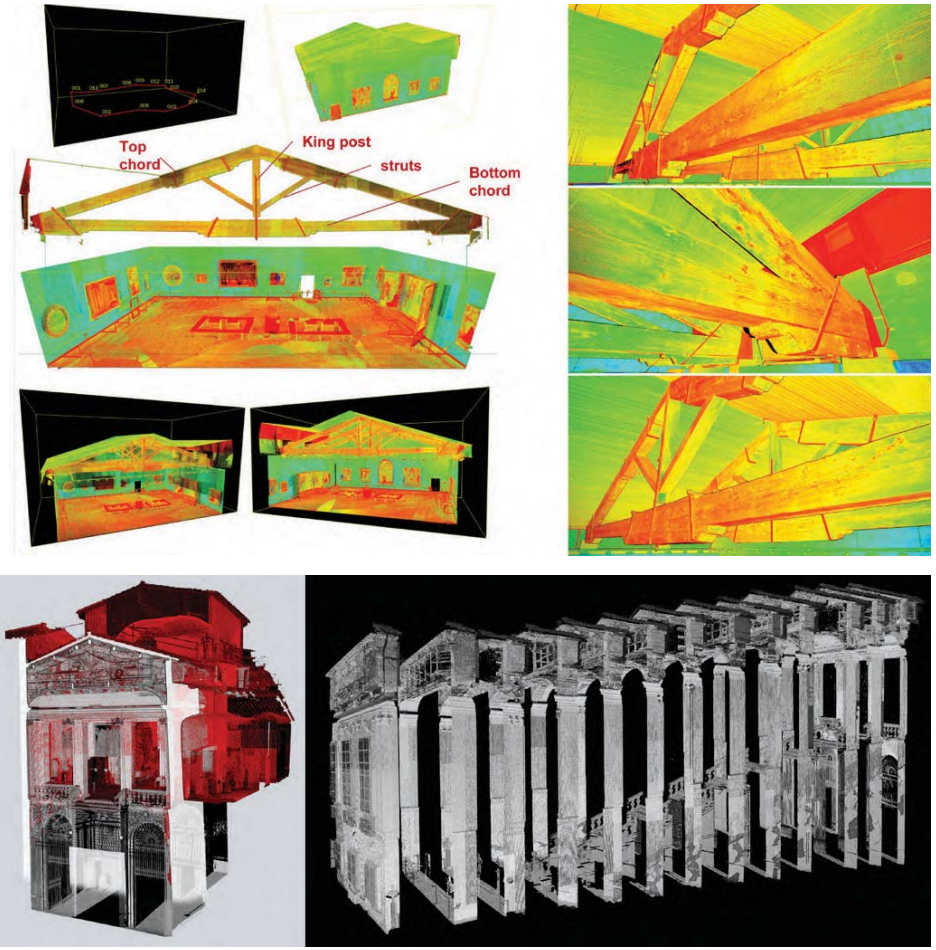


Fig. 8-9 Above: images of Botticelli's Room with the wooden trusses of the roof. Detailed scans were done in order to collect the exact dimensions of each element. Below: The Lorenese Staircases with extrados and intrados areas. Many progressive sections were produced to study the wooden ceiling.

Uffizi Project: Morphological analysis and monitoring activities of specific structural elements. Detailed progressive sections both in longitudinal and transversal orientation. With this series of sections made every 5-20 cm it was possible to gain detailed control of the architectural assessment of the ceiling and wooden trusses investigated. The metric scale is 1:5 cm because of the necessity to achieve the highest level of detail possible (Figures 8 and 9).

Nativity Church Project: Documentation and representation of the church with real photomaps for restoration activities on the timber structures and plaster walls. Materials elaborated: CAD drawings of floor plans, sections, facades in 1:25 scale. General plans for understanding the volumetric entity of the architectonic complex. Photomaps of all the inner and external walls. Experiments in photo-modelling the mosaic and timber surfaces to understand the level of detail achieved with this process (Figures 10 and 11).

In the post-production phase, after the survey operations in the field, it is important to check each ScanWorld and clean them one by one from different types of noise and useless element scanned, for example objects in the field, furniture, the presence of people passing in front the laser while it is working and massive vegetation that may cover the main object being analysed. In addition to this, it is possible to use the Cyclone software[15] with a layers list for isolating specific elements and to be able to have a more cleaned organisation of the data within the point cloud file. In the Cyclone software, the surveyor defines the cut-planes for making the sections. When the section is elaborated on the point cloud it is possible to create orthoimages and export them in a .bmp file. These images will be loaded into a CAD file and moved in their specific reference

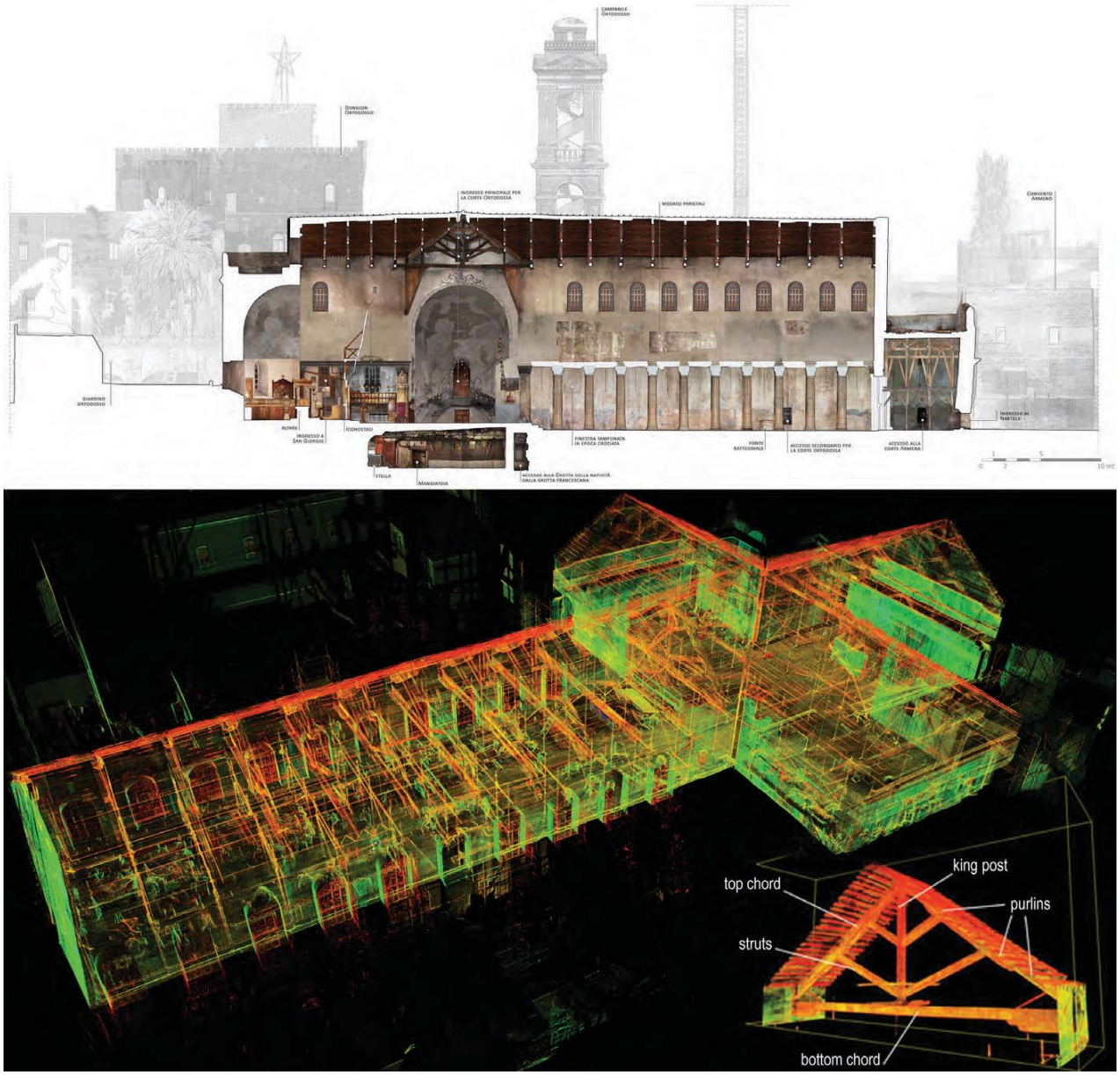


Fig. 10-11 Above: Longitudinal section of the Nativity Church with application of real photomaps to analyse damage. Below: detailed view from the point cloud of the wooden roof structure of the Nativity Church with a zoom on atypical timber truss.

positions thanks to the coordinates assigned by the software while exporting the orthoimage. When all the orthoimages of a section are loaded into the CAD file it is possible to start drawing the section. In addition, a technical layer list is set and defined in AutoCAD according to the main rules for the representation of the architecture and environment.[16] All the material produced needs to be archived with specific organisation in order to give different operators and technicians the possibility to handle the quantity of data and navigate within the database. For this reason, laboratories, units and departments should define and agree specific storage systems for their research work. It is interesting to notice that even if each case study had a specific output and purpose, all of them started from accurate survey operations. The challenging aspect of this method and procedure is being able to cover many necessities even in different scientific areas: landscape analysis, architecture, engineering, dissemination and sociological needs (for touristic reasons for example) and historical and archival needs. It is certainly possible to assume that a laser scanning survey may be necessary not only for the main reason for which it was requested but also for future reasons that may arise. The research experiences illustrated in this contribution have definitely underlined and confirmed that today our world heritage should have as a rule metric documentation performed through a laser scanner survey, in order for this to be available for any future need.

Conclusions on the research experiences

This research proves that the laser scanner survey represents a fundamental documentary base that any heritage site should have. From a laser scanner, in fact, many different types of project can be formulated with intentions ranging from the simple updating of cartography and technical drawings, up to restoration and consolidation projects, and also projects related to more educational aims for dissemination purposes such as touristic info and virtual navigations (Figure 12).

The results of these research activities have highlighted that the development of intervention strategies for the preservation of cultural heritage must today be based on updated documentation. It is evident that the careful acquisition of data has a fundamental role in validating each decision in any sector of detection. The importance of the documentation becomes even higher considering conservation in its widest sense, thinking about "physical characteristics" and "immaterial intrinsic elements", in consideration always of the principle of the "minimum intervention and maximum retention of materials".[17] Today the main urgent needs are related to the ascertainment that:

- The use of cheap and nontraditional materials is altering and undermining the structural image of wooden heritage
- A renewed necessity for skilled carpenters needs to be resolved in order to keep specific knowledge alive and available for the future
- Traditional materials, crafts and craft techniques must be disseminated and spread using training programmes

Fig. 12 A virtual reconstruction of the wooden village of Yamka on Kizhi Island, Karelia, Russia. The 3D model has been realised starting from the real dimensions obtained from the laser scanner survey. Real photomaps were used to map the buildings. This 3D model could be used for virtual navigation within an exhibition or directly on the Web.

and specific studies addressing the sustainability of traditional materials and craftsmanship.[18]

- Related to practical strategies with laser scanners and monitoring assessments, it would be useful to leave in place the surveyed documentary targets in order to obtain the same metrical joint system throughout the years. Periodical surveys can aid the technical and deep understanding of timber structures in order to check their state of maintenance and operate with fast, safe coherent actions when needed

The loss of knowledge of this wide wooden heritage, the disappearance of the traditional cultural identity, the memory of these places and the loss of knowledge of craft techniques are seriously compromising the conservation of wooden traditional architecture. The elaboration of new typologies of analysis and intervention strategies for wooden heritage represents a strong, highly urgent necessity. Companies, academic units, and state entities should start to invest in this sector, asking for updated documentation and financing courses for carpenters and craft technicians in order to keep this precious part of our history of architecture alive and available for the next generations.[19]

Endnotes

1 The main bibliography is listed below.

2 The synthesis of the studies conducted is represented by my Ph.D. final work published with Firenze University Press editor. S. Porzilli, *Rilevare l'architettura in legno. Protocolli metodologici per la documentazione delle architetture tradizionali lignee: i casi studio dei villaggi careliani in Russia*. Firenze: Firenze University Press. pp. 269. ISBN 978-88-6453-354-4.

3 Marco Vitruvio Pollione, *De Architectura Libri X*, Franca Bossalino, Edizioni Kappa, Roma, 2002, pp. 74-75.

4 Knut Einar Larsen, Nils Marstein, *Conservation of Historic Timber Structures*. An Ecological Approach. Oslo, 2016.

5 This project was carried out between 2009 and 2011 by the University of Florence, Italy – Department of Architecture DIDA. The Project Coordinators were: Prof. S. Bertocci and Prof. S. Parrinello. In this case the drawings and results come from the Master's Thesis work of Sara Porzilli and Aurora Sorini, who graduated in July 2011, entitled La Pogost dell'isola di Kizhi, rilievo laser scanner per l'analisi della struttura architettonica della Chiesa della Trasfigurazione (English: The Pogost Complex on Kizhi Island: laser scanner survey for the architectonical structural analysis of the Church of the Transfiguration).

6 C. Norberg-Schulz, *Genius loci. Paesaggio ambiente, architettura, collana Documenti di architettura*, trad. it. di A. M. Norberg-Schulz, Electa, Milano, 1992.

7 Museovirasto - National Board of Antiquities (NBA) which has its main office in Helsinki (Finland) represents the main management of the Lamminaho Farm House. Senatti Properties is the second partner which has financed the activities.

8 Manager and coordinator of survey operations: Prof. S. Parrinello, University of Pavia, Italy. Surveyors involved in the survey of the Pogost Complex: Sara Porzilli and Aurora Sorini responsible for post-production and results.

9 Research activity carried out at the University of Florence jointly with the University of Pavia, Italy. Manager and coordinator for DIDA: Prof. S. Bertocci. Manager and coordinator for DicAr: Prof. S. Parrinello. Technical coordinator and surveyor for the results shown: Ph.D. Arch. Sara Porzilli. Other collaborators: Ph.D. Arch. Francesca Picchio, Pietro Becherini.

10 Project carried out by the University of Florence, Italy and University of Pavia, Italy. Scientific managers of the survey project for DIDA: Prof. S. Bertocci. Manager and coordinator for DicAr Prof. S. Parrinello. Restoration Company responsible for the work on site: Piacenti s.p.a. Technical Coordinator: Ph.D. Arch. Sara Porzilli. Surveyors: Pietro Becherini, Monica Bercigli, Matteo Bigongiari, Francesca Picchio, Sara Porzilli, Mattia Ventimiglia.

11 The term "integrated" is specifically intended for those research projects where different types of survey activities are carried out concurrently.

12 "Target" is a technical term that indicates a specific point (sometimes with specific reflective surfaces) used for combining different scans. Thanks to these points it is possible to connect point clouds obtained from different scan positions using geometrical algorithms.

13 For the Lamminaho project the company Mitta Oy from Finland, and the "Survey Lab" located in Oulu arranged the technical equipment and software used for processing the data. They also supported the post-production operations.

14 These terms come from the technical characteristics of laser scanners. They are related to the resolution of the point cloud in relation to the distance between the laser position and the object surveyed.

15 Cyclone is the official software from Leica GeoSystem used for handling point clouds: https://leica-geosystems.com/.

16 S. Bertocci & M. Bini, *Manuale di rilievo architettonico e urbano*, Città Studi edizioni, Torino, Italia, 2012.

17 Knut Einar Larsen & Nils Marstein, *Conservation of Historic Timber Structures*, pp. 10-11.

18 These principles are already underlined and treated in the ICOMOS International Wood Committee's Principles. This contribution aims to underline and confirm these urgent necessities with practical examples.

19 Lars Petterson, *Suomen Kansanomainen rakennustaide*, Oma Maa 4, WSOY, 1958.