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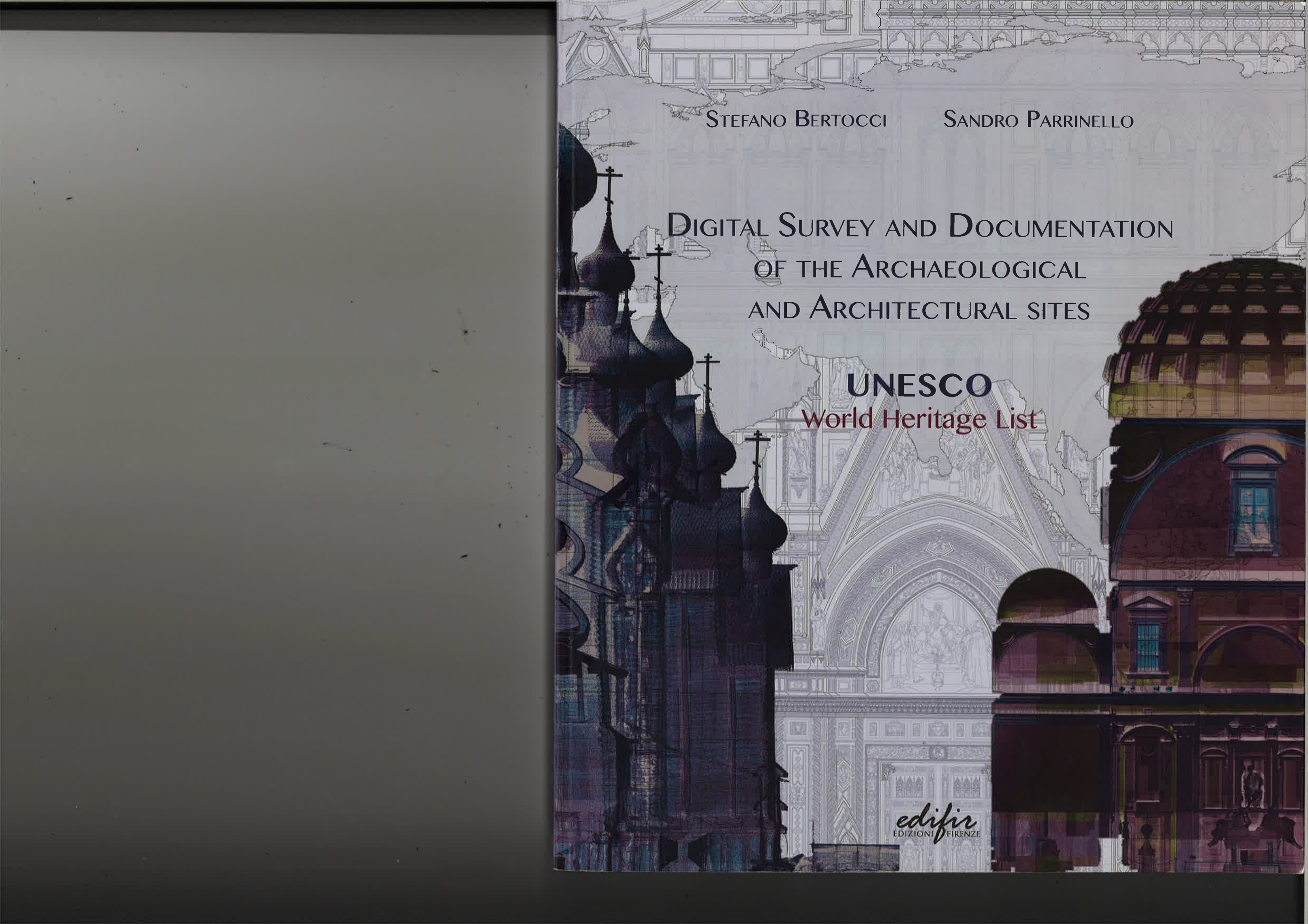
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STEFANO BERTOCCHI

SANDRO PARRINELLO

DIGITAL SURVEY AND DOCUMENTATION
OF THE ARCHAEOLOGICAL
AND ARCHITECTURAL SITES

UNESCO
World Heritage List

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The background of the page is a detailed line drawing of a Gothic cathedral facade, featuring multiple levels of arched windows, statues in niches, and a large rose window. A semi-transparent map of the world is overlaid on this drawing, with the continents of Europe, Asia, and North America clearly visible. The map is positioned such that it appears to be a window or a layer revealing the world behind the architectural drawing.

A research on several UNESCO World Heritage Sites allowed to experience the most advanced technologies in the field of survey for digital documentation of the architectural and archaeological heritage. An overview of these studies in nine different countries, in Europe, Asia and America, dealing with architectural remains interesting from an architectural viewpoint, shows the significant results achieved through specific devices and methodologies.

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STEFANO BERTOCCI

SANDRO PARRINELLO

Digital Survey and Documentation
of the Archaeological and Architectural sites

UNESCO
World Heritage List

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2000-2010

This publication takes part in the series “Drawing, Survey and Design,” that have a college of international referees. “Digital Survey and Documentation for the Archaeological and Architectural UNESCO World Heritage List” has a Scientific Committee and the text was submitted to a committee of three referees composed of two Italian members and a foreigner. “Digital Survey and Documentation for the Archaeological and Architectural UNESCO World Heritage List” is a peer-reviewed book.

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ON COVER: DRAWINGS RELATED TO THE SURVEY OF THE CHURCH OF THE TRANSFIGURATION OF POGOST KIZHI (RUSSIA), THE “SACRESTIA NUOVA” IN THE COMPLEX OF THE MEDICI CHAPELS IN SAN LORENZO IN FLORENCE, AND DRAWINGS RELATED TO THE FACING WALLS OF FLORENCE CATHEDRAL. COMPOSITION AND GRAPHICS BY FRANCESCA PICCHIO

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This volume is published on the occasion of the exhibition “Documentation and digital survey of the Architectural and Archaeological Heritage protected by UNESCO” which was held in Florence, in the palace of Orsanmichele from 06/11 to 30/11 2014. The exhibition has gathered some examples documentation of work concerning UNESCO sites performed by the Interdepartmental Joint Laboratory “Landscape Survey & Design” (Department of Architecture, University of Florence and Department of Civil Engineering and Architecture, University of Pavia) and the Laboratory of Survey of DIDA-labs (Department of Architecture, University of Florence)

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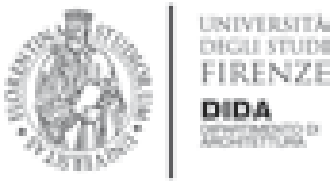
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DOCUMENTATION TECHNOLOGIES

EXPERIENCES OF THE INTERDEPARTMENTAL JOINT LABORATORY “LANDSCAPE SURVEY & DESIGN” AND OF THE LABORATORY OF SURVEY “LRA”

The scientific results completed in two decades of experiences even in several sites classified by the UNESCO World Heritage List, from the Joint Laboratory of Landscape Survey & Design and the Laboratory of Survey LRA of the Department of Architecture of the University of Florence, have allowed us to bring together the most advanced technologies in survey knowledge for the digital documentation of the architectural and archaeological heritage.

Are presented in this work a summary of numerous studies, conducted in Europe, Asia and America, which have found their fullest expression in a large corpus of studies conducted with international cultural cooperation and collaboration, as well as government institutions, with important cultural administration, universities and technical offices of the Heritage, and it offers a unique over view of the experiences of numerous experiences of documentation and surveys realized on these sites.

It is evident that the collection of the experiences of documentation shows the maturation, during more than the last decade, of specific tools and knowledge processing and different results, obtained in post production phase, in relation to the specific needs of the architectural and archaeological heritage UNESCO World Heritage Site.

Infographic technologies and digital detection systems, as it tends to show the exposition, can be profitably used in various different studies on the cultural, architectural and environmental heritage. In particular we offer many applications that are related to the management aspects of the extensive digital documentation that accompanies the research taking place in a specific site.

Due to the development and dissemination of innovative IT solutions for cultural heritage, nowadays are also to be taken into consideration, their preservation and maintenance in an environment of digital management. These technologies are essential for the documentation of the life cycle of an opera of the Cultural Heritage these contributions are functional to ensure highly effective for the management and its maintenance, as well as its use conscious. We are moving towards the integration of knowledge and existing structures (for example information systems of public and private institutions for the conservation, research centers and museums) and the role that the sector of digital documentation must cover may become increasingly relevant.

The theme of the knowledge of heritage is of primary importance in the legislative framework which frames the UNESCO-protected World Heritage Site; through the numerous experiments developed and the various scientific contributions presented was carried out an initial survey of methodologies for the documentation of sites of interest that, in the context that we propose for the research, as well as becoming a qualified point of reference for researchers could be a meeting place for dealing the themes related to the issues of conservation and eventual recovery or reuse, of many sites, in line with what is prescribed by the Management Plans for UNESCO. In the exhibition are illustrated through digital surveys, virtual models, videos and drawings, the following of the UNESCO World Heritage sites, concerned by studies and surveys conducted by our research laboratory.

During these years we have developed a research group that has involved several specific knowledge of professors and researchers of the University of Flor-

ence and Pavia who have been able to consolidate relations with Italian and foreign institutions, on the basis of specific cooperation cultural agreements concerned, and to build relationships with companies interested in the development of technologies and applications specific to the development of research.

A strategy of promotion of cultural heritage must be up to date in the objectives, strategies and purposes chosen, for these reasons must be based on a strong and modern apparatus of knowledge of the assets studied. Regardless of the type of intervention chosen is clear that a careful analysis of the data acquisition plays a fundamental role for the next address of each decision and an organic strategy on a real project of knowl-

edge is the necessary premise of the project for the preservation and enhancement. The appearance of the documentation becomes even more important when the policy of conservation concerns both the physical object that the immaterial memory of the historical, artistic and cultural artifact that maintains and forward in time.

Years of experience in defining political, scientific and technical protection of cultural heritage in Italy show that is now overcome the phase of single cataloging and location of the assets to be protected and it seems increasingly necessary to activate systems for the protection of cultural heritage and artistic more integrated and technologically advanced.

STEFANO BERTOCCHI SANDRO PARRINELLO

Presentation

SAVERIO MECCA

Director of the Department of Architecture University of Florence

The Department of Architecture DIDA is a structure of the University of Florence dedicated to scientific research, educational and formative activities, transfer of knowledge, innovations of the activities addressed to architecture, industrial design, territorial and landscape planning.

The Department of Architecture promotes and organizes the valorization and transfer of the research results also cooperating with other Universities, public and private institutions, as it is underlined in the book that we are presenting.

The Department of Architecture promotes the internationalization of the research activities, of the valorization and transfer activities, of the scientific and technological advice, even in cooperation with other academic and research structures, both public and private. The DIDA, looking forward to these aims, organized an internal system of laboratories by instituting the DIDALABS. The mission of the DIDALABS is to support, both scientifically and technically, the education, the research and the higher formation, the transfer of knowledge of the DIDA and of the Athenaeum in the

areas of architecture, industrial design and landscape and territorial planning area.

Above all, the Survey of the Architecture Laboratory LRA is our structure predisposed to the formation and research above the Architectural and Archaeological Heritage. It produces surveys of the architectural, the urban and landscape complex integrating the competences that are now being employed in the sectors of documentation and preservation of the Heritage. These activities may also support the public and private institutions operating in the sector of Cultural Heritage.

The knowledge transfer represents the fundamental element, which can valorize or potentiate the formative offer through the conducted scientific experiences. In addition, these experiences permit to tune the operative methodologies for the digital survey, giving essential instruments in order to understand and evaluate the preservation and restoration interventions. A heartfelt thanks goes then to all our teachers and researchers who have contributed to the development of research in the field of cultural heritage protected by UNESCO which are now collected in this volume.

CARLO CIAPONI

President of the Faculty of Engineering University of Pavia

I am honored to present this book that collects contributions for multiple experiences of research on the topic of architectural documentation, particularly complex and articulated. The management of the historical heritage, the preservation of cultural memory, are necessary activities that concern and cut across a variety of different disciplines, whose complexities are evident as long as they require a specific definition of the identity of the architecture.

The activities developed by the laboratory that include University and Company, involving the Department of Civil Engineering and Architecture from the University of Pavia and the Department of Architecture from the University of Florence, include several examples of case studies relating to UNESCO sites, investigated with the architectural survey and the Science of drawing, expliciting in these pages the technological development that has focused on the representation of architecture during these recent years outlining paths of inquiry through which to define methodologies and operational protocols for the understanding of the historical and monumental complex. The research presented often involve students, graduate students or PhD students, increasing the value of the experience with that of advanced training and education

in a sector in which knowledge can be developed only staying in contact with the survey site. I believe that the occasion of this exhibition, which presents a full program of roundtables and meetings, represents an important opportunity for dialogue and scientific exchange on the subject, being able to offer excellent points of reflection for students of architecture and those in charge of protecting historical heritage.

Know in depth a building, especially when its historical and cultural value is strongly established, as in some cases that will be presented here in this exhibition, is the basis for the preparation of a conservation project that will necessarily be caught and not just aimed at the preservation of the but its transformation so that it can be revived and returned to the community.

I believe that all phases of the survey and analysis of a monumental property without hesitation could be define purely an architectural project.

A big thank you to the organizers and members of the research groups that have helped to enrich their experiences and reflections with the many issues on the subject of digital documentation of UNESCO Heritage, while developing sensitivity for its protection and conservation.

MARCO BINI

University of Florence

After a long talk with Guido Vannini, an archaeologist medievalist, friend of mine since the time of the excavations made for the repaving of Piazza della Signoria in Florence, about our similar experiences, relative to the documentation and the studying of ancient sites, he asked me to take part to the archaeological mission in Petra (Transjordan) to survey the mediaeval settlement of Wu'Arya, part of the UNESCO World Heritage. At that time Stefano Bertocci, who was about to end his PhD in Surveying and Representation of Architecture and Environment, accepted to participate at the research in Petra, first of all with his PhD final work and then with his fundamental commitment for several years. The missions undertaken together, the conferences to which we took part and those that we have organized are a strong witness of this commitment: above all I want to remind the XI international seminar FORUM UNESCO University and Heritage, which was devoted to “documentation for conservation and development — new heritage strategies for the future”, held in Florence in 2006. We organized this seminar in the faculty of Architecture of Florence to emphasize the results of the researches of analysis, documentation and valorization of the architectural assets and of the material and immaterial heritage that it involved hundreds of scholars from the whole world.

This volume, with the exhibition that matches it, represents the natural evolution of the interest toward the sites of universal importance. In addition, it follows the aim to connect two big realities of the cultural world such as Heritage and University, by using a network to exchange information, search and find competent sources, promote and facilitate the dissemination of research in a scope of international cooperation with the only purpose of preserving the culture. The execution of knowledge, documentation and study programs coordinated by Stefano Bertocci and executed by his team of young researchers and the related net of internationals study, constitute the fundamental base to exercise fruitful investigative

critical activities. These activities are strictly connected to the creation of an irreplaceable documentation for the conservation and sustainable development of a settlement, city or landscape, and to foresee the needed interventions of preservation and valorization planning, aimed to promote the conscious progress of the human activities.

The many sites documented in the volume have been documented and severely surveyed with tested and verified instruments, applying the more appropriate and updated methodologies for the studied artifacts. From the archaeological ruin to the decorative apparatus of frescoed walls, from complex wooden artifacts, like the monumental church in Kizhi (Karelia), to monuments fundamental for the history of the architecture, such as the Baptistery and Dome of Pisa or Michelangelo's sacristy of San Lorenzo, just to name a few of them.

The international activities of documentation and study world heritage and important monuments are particularly relevant: from the South America to the Middle-East countries, from the eastern European countries to Israel where the ancient site of Masada was surveyed. In Masada the survey campaign carried out constitutes an irreplaceable instrument for the studying of the conformation of a morphologically complex place where the many traumatic events, that succeeded one another along centuries, has permitted the stratifying of physical evidences with specific technologies and ways of working. The “raison d'être” of the survey is in the production, through adequate tools of representation, of a documentation as exhaustively as possible. This can give a certain number of information “mediated” by the operator, which allow us to understand the logical and formal structure, the utilization and the functional organization of the architectural complex in every time of history, contributing to the preservation and dissemination of unique cultural heritage, with universal value.

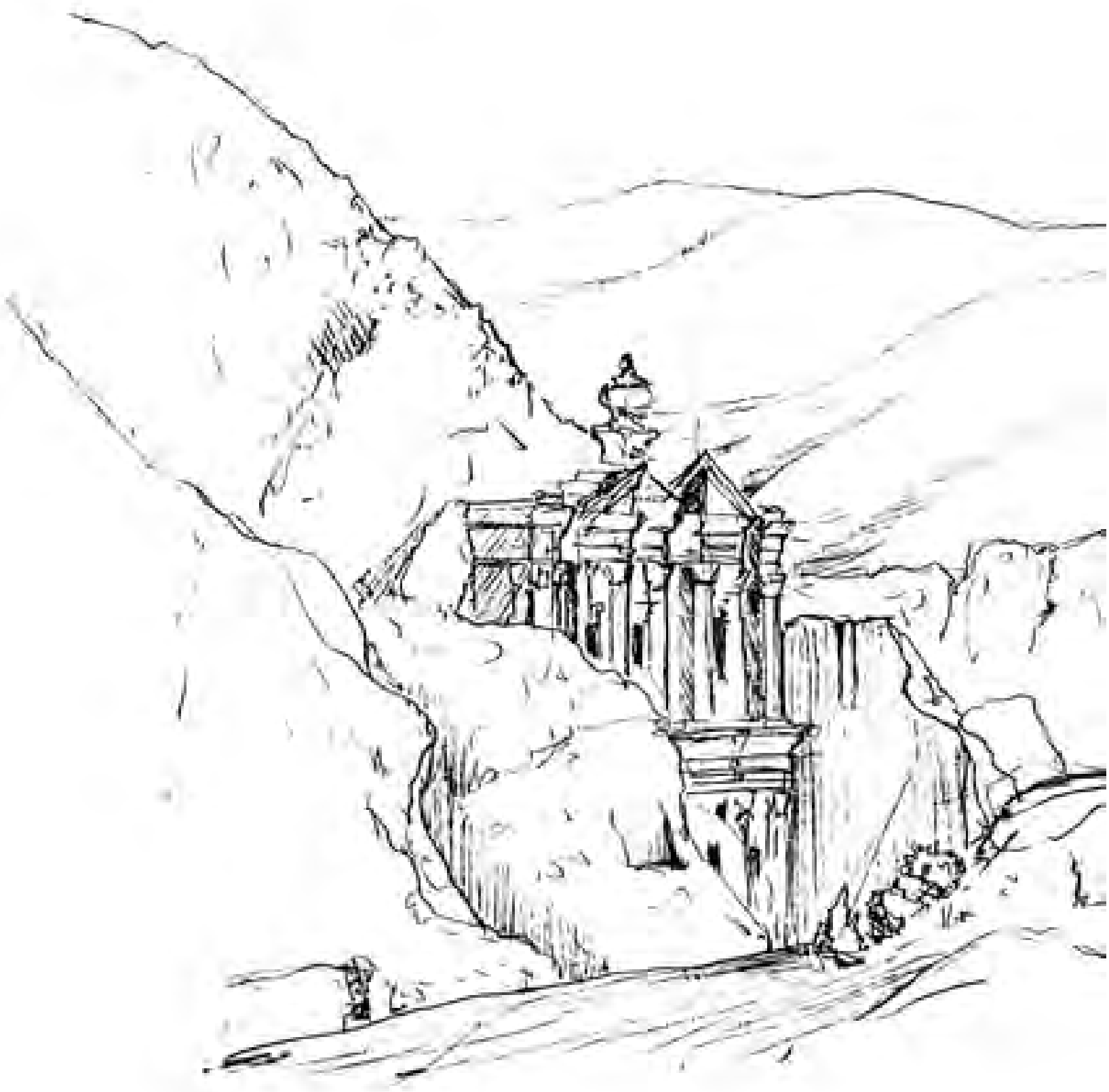
MARICRUZ PAILLES

Instituto Nacional de Antropología e Historia, Conaculta, Mexico

Nos encontramos reunidos en el espléndido recinto de Orsanmichele, para apreciar los resultados obtenidos de los trabajos realizados por el Laboratorio Conjunto Landscapes Survey and Design de la Università degli Studi di Pavia y de la Università Degli Studi di Firenze, resultado del conjunto de varias disciplinas aplicadas con rigor científico, el análisis detallado de los datos, la investigación documental, la interpretación de los registros arquitectónicos y arqueológicos además de la utilización de nuevas y sofisticadas herramientas tecnológicas, todo esto con el fin de sacar a la luz los elementos que conforman la memoria histórica y cultural velada por el paso del tiempo, que guardan cada uno de los monumentos y sitios presentados en esta exposición, ubicados en diversas regiones geográficas del mundo. La búsqueda de las señales que el devenir histórico ha dejado en ellos, como conocer la causa y origen de su diseño, el por qué se utilizaron ciertos materiales para su construcción, las técnicas de ingeniería y arquitectura que se aplicaron para su edificación, que finalmente son el resultado de la transposición de modelos culturales, expresados en los bienes patrimoniales arquitectónicos y arqueológicos. En esta exposición intitulada Documentación y Registro Digital de Bienes Arquitectónicos y Arqueológicos de la UNESCO, tendremos la oportunidad de observar como la tecnología avanzada con el levantamiento mediante sensores remotos, la utilización del Laser Scanner 3D y 2D, el registro fotográfico y topográfico para lograr un levantamiento integrado, que a su vez permite mediante el análisis de la base de datos obtenidos en el trabajo de prospección desarrollar los instrumentos para la gestión, conservación y puesta en valor de monumentos aislados y complejos arquitectónicos y arqueológicos de los bienes patrimoniales de la UNESCO, entre los que se encuentran en la región del Medio Oriente Pasagarda en Iran, Masada y Acri en Israel, La Natividad de Belem en Palestina y Petra en Jordania. En Europa destacan los bienes patrimoniales de Italia con la Villa de Adriano en Roma, la Piazza Armerina en Enna, la Piazza dei Miracoli en Pisa, el Palacio de Podesta en Mantova cuya intervención fue a consecuencia del sismo ocurrido en el año 2012, con la documentación y registro del monumento fue posible evaluar con precisión los daños y afectaciones que sufrió el edificio por causa de este desastre natural. De Florencia la magnífica ciudad anfitriona de este evento

se presentan la Piazza del Duomo, el Gabinete de Miguel Ángel, el Palacio Pitti y las villas Medici, finalmente la Isla Kishi en Rusia. En América tenemos Ouropetro en Brasil y las fortificaciones levantadas en las costas del Caribe por los Antonelli, una familia de ingenieros militares y arquitectos de Gatteo, Italia, que durante tres generaciones y a lo largo de casi cien años entre la segunda mitad del siglo XVI y la primera del siglo XVII realizaron obras al servicio de los reyes Carlos V, Felipe II y Felipe III de España, en la Península Ibérica, Norte de Africa y el Caribe Americano. Entre sus construcciones de defensa en el litoral caribeño se encuentran la fortaleza de San Juan en Puerto Rico, las fortalezas de la Habana y de Santiago de Cuba, la fortaleza de Portobello y de San Lorenzo en Panamá. Quiero mencionar que el registro y documentación de las Fortificaciones en el Caribe, es parte de un proyecto que tiene como objetivo valorizar las estructuras de carácter militar construídas estratégicamente a lo largo de las costas del Mar Caribe por los Antonelli, como medidas de protección ante los ataques de los piratas y corsarios holandeses, franceses e ingleses entre ellos Francis Drake y John Hawkins, que ponían en peligro los territorios y riquezas de la Corona española en América. Las obras de los Antonelli se pueden considerar un vínculo cultural entre la tradición del Renacimiento Italiano y sus expresiones arquitectónicas en las colonias americanas. En esta exposición podemos ser testigos de una larga tradición de las universidades y organismos gubernamentales de Italia de colaborar estrechamente con la UNESCO para conservar, registrar, rehabilitar y proteger los Bienes Culturales que son Patrimonio de la Humanidad. Esta colaboración se remonta al año de 1960 cuando Italia junto con España, Alemania y Estados Unidos de América, respondieron al llamado del Secretario General de la UNESCO para adherirse a una campaña internacional dirigida a rescatar y salvaguardar los monumentos y sitios de Nubia que iban a ser afectados por la construcción de la Presa de Aswan en Egipto. Así es que 54 años más tarde, nos encontramos en este recinto ante los resultados de un proyecto de colaboración internacional que incorpora la tecnología del siglo XXI para registrar, documentar, conservar y proteger los Bienes Culturales inscritos en la Lista de Patrimonio Mundial de la UNESCO, proyecto conjunto de la Università degli Studi di Firenze y la Università degli Studi di Pavia.

Essays on Architectural Survey



12/10/95 JB

Experiences of documentation and digital survey of some UNESCO World Heritage Sites

Stefano Bertocci

DIDA – Department of Architecture, University of Florence

INTRODUCTION

The scientific results completed in two decades of experiences in numerous UNESCO World Heritage Sites, before as a researcher and then as founding member of the *Laboratorio Congiunto "Landscape Survey & Design"*¹, founded in the Department of Architecture of the University of Florence and recently joined also by the Department of Civil Engineering and Architecture of the University of Pavia, allowed experience the most advanced technologies in the field of survey for digital documentation of the architectural and archaeological heritage. All this knowledge is now involved also in the Laboratory of Survey LRA of the Laboratories of the Department of Architecture of the University

of Florence named DIDALABS². Various studies conducted in nine countries (17 campaigns in protected heritage sites) in Europe, Asia and America³, were carried out especially in the perspective of a cultural international cooperation and in collaboration with government authorities and local administrations, as well as with the state authority of each nation and with the coordination of the Italian diplomatic delegations, with important cultural institutions, universities and administrative offices involved in Architectural Heritage. Through the synthesis of these works and studies, a singular overview can be offered to the scholars of this field, experiences materially built during the research surveys in heritage sites with architectural remains of ar-



Opposite page: view of the tombs (al-Deir) “monastery” in Petra. Above: view of the citadel in Amman (Jordan)



A triclinium funerary in Beida near Petra (Jordan).

archaeological interest, that show influences, connections or cultural and compositional models, and that required in-depth analysis and, above all, the research of specific tools and knowledge processes and the elaboration of results gathered in relation to the particular context. All pledged to match the traditional and still indispensable direct and 'sight' survey, to the most innovative and sophisticated technologies, to define the relevant procedures, to develop and optimize the appropriate methodologies and specific protocols. Starting from the metric and formal detection of the monument, as first data of consistency of the architectural asset, it is possible for the searchers to reconstruct the thread of its story through the layering of the interventions since founding until today. Further analysis must be related to one another and with the measured shapes, to enrich the knowledge of the architecture. A specific expertise has

been configured, unique in the world, based on a wealth of specialist knowledge and skills of the highest level. It is one of the true excellences of the Italian university system and of the entire country, and it was born experimentally working in the field. In the present work we present a number of case studies related with UNESCO heritage protected sites, examples of works produced by highly qualified experts and technology transfer centres that operate through a net of relationships with business enterprises, the Italian and foreign governments and other institutions.

HERITAGE AND MANAGEMENT PLANS

The theme of the knowledge of Heritage is of primary importance within the legislative framework relating to the World Heritage Site protected by UNESCO; through the various researches we undertook an initial census of the more proper methodologies for the documentation of the sites architecturally and historically of interest.

In this context and for the development of the research, these methods can become a point of reference for scholars, and also be the purpose of the discussion with themes concerning conservation and possible restoration or re-use of many sites, in line with the requirements of UNESCO Management Plans. In order to highlight the importance of a proper management of the Heritage, in 2002, during its 26th session, the World Heritage Committee adopted the "Budapest Declaration".

All partners were exhorted to support the preservation of the World Heritage through some fundamental strategic objectives, trying to ensure a fair balance among conservation, sustainability and development. In this way the World Cultural Heritage can be protected through appropriate activities contributing to the socio-economic development and to the life quality in our communities; moreover through communication programs of actions and education, research, development and awareness strategies; finally, looking for an active involvement by local authorities, for the protection and management of the World Cultural Heritage.

Each request for inclusion in the World Heritage List must therefore include a management plan, with a complete description of the way to protect the unique value of the site. The primary objective of the management plan is to ensure an effective protection of the heritage, and to ensure its preservation to future generations. For this reason, the Management Plan should consider the typological differences, the characteristics and peculiarities of the site and of the cultural and/or natural environment where the heritage is located.



Drawings of Jerusalem from the garden of Gethsemane, and view of the exterior and interior of the Holy Sepulchre in Jerusalem.

It should also adopt the existing planning systems and/or other traditional methodologies of territorial organization and management. In the case of serial sites, and/or transnational sites, the Management Plan should ensure the coordination in the management of the single components of the site⁴.

It is clear that the specific activities of our disciplinary field, survey but also drawing, are irreplaceable tools for descriptions analysis of formal, materials and structural features of a building and its context; the results of such activities are essential for the preliminary step of any project or program⁵.

Nowadays, in a general context that considers the specificity and the skills of the surveying specialist useful for the conservation and restoration project, there is an increasingly great interest towards this profession in the field of archaeological researches, insomuch as to become an independent sector.

Today the term “context” has cultural, chronological, but also spatial and environmental meanings: the architect, being an expert in describing events in terms of space and environment, can therefore be included with good reason among the scholars who, in the specific field of each archaeological research, have a key role like other professionals: experts in charge of the excavation and of recording the finds work together with archaeologists, historians, architects, restorers and laboratory technicians.

TOOLS AND METHODOLOGIES USED IN SOME CASE STUDIES

Info graphic technologies and digital surveying systems can be used in various fields of archaeological studies and, first of all, they offer numerous applications concerning the management of the extensive documentation of the excavation and survey for each campaign. Generally one



The Loggia dei Lanzi with the rape of the Sabine Women by Giambologna in Florence.



View of the Church of St. Francis of Assisi in Ouro Preto, Minas Gerais, Brazil.

View of a portion of the town of Ouro Preto, Minas Gerais, Brazil.

of the main purposes is to prepare a database concerning the documentation of each site, that can be easily accessed and updated, organized in order to be online accessible and at research teams disposal, even internationally, due to the interdisciplinary nature of the study. These databases are essential tools for the management and the archiving of survey documentation, for instance of notes taken during the fieldwork, of surveys made by means of digital equipment, of source files up to definitive documentation and drawings, of images and pictures. If well organized, this data gathering can offer the possibility to carry out studies for didactic works or researches in various fields. The introduction of such devices, adapted to the requirements

of each different sector, allows the enhancement of the wide iconographic and documentary material gathered by a team of scholars and experts working in a particular area⁶. In the end, another distinctive element is the GPS georeference of the topographic data of the buildings described by the drawings, that allows a quick maps updating with any new information (e.g. excavations campaigns).

Digital maps can be the support for the gathering of GIS data systems, useful for researches that are directly based on the cartographic map of the site, and they can provide thematic maps for each different level of the study.

In the Petra site various survey campaigns were carried out within the framework of the Italian mission concerning



View of the Church of Our Lady of the Rosary in Ouro Preto, Minas Gerais, Brazil.



View of the interior of the church of Our Lady of Pilar in Ouro Preto, Minas Gerais, Brazil.

the study of the settlements of the Crusader epoch. The project, started in 1992 with annual campaigns until 2002, produced a topographic survey at the architectural scale of the main Crusader sites (the castles of Wu'ayra, Habis and Shobak), which allowed scholars to study and even today are still in use and in process⁷.

The same topics, but properly updated from the point of view of digital technologies, are the main objective of the research on the site of Masada in collaboration with the Shenkar University of Israel, where we are experimenting all the possibilities for data acquisition and processing integrated systems, focused on the particular morphological conditions of the site.

Thanks to the campaign of Winter 2013 the gathering of a large amount of data was disseminated through a Publication, planning new developments for 2014.

In this case an accurate organization of the research structure is necessary, in order to focus on the general objectives from a technological point of view, concerning the practices of digital survey that will be used, and from the point of view of the planning of survey activities for a so wide site and with many important elements can require activities with a three-year program⁸.

The application of survey and architectural representation in archaeology is increasingly oriented towards a shared system of data acquisition and graphics processing



Detail of the facade of the Cathedral of Havana, Cuba.



View of a pavilion in the park of the Palace of Catherine in St. Petersburg, Russia.

that make the integrated survey a methodology with a technological and experimental evolution.

The product of the survey, both the architectural aimed at defining the spatial qualities of a space, or the archaeological one, aimed at accurately describing the building surfaces⁹, is the result of several activities, requiring a more and more quick data acquisition, not only with metric reliability, but also with more immediate descriptive qualities.

Photography, which is nowadays an essential tool in the context of a survey, is used in all the processes of environmental survey: even a non-expert in architectural survey from a scientific and technical point of view, can carry out a campaign with adequate digital devices.

With some applications of digital photography, not only the majority of the dimensional and qualitative aspects of a place can be gathered, but it is also possible to geometrically reconstruct space, in order to obtain three-dimensional models to better understand the object, both from a morphologic point of view and for its materials.

The data acquisition step and the processing step of a part of the archaeological site of Masada, by means of an accurate photographic survey campaign, was aimed at the creation of three-dimensional models directly from pictures, describing the current condition of the monument and comparable with the point cloud from the laser scanner in order to verify the metric reliability and if present some dimensional differences.

The 'structure from motion' processing are used for the construction of virtual models, often directly created from photographic images.

The quick data acquisition and the quite rapid creation of models made this tool increasingly interesting for the field of survey, moreover the possibility to use them in an interactive virtual environment can disseminate to a wider public the awareness of the places.

An example of the development of these methods is shown by the results of the survey campaigns carried out in 2013 at Villa Adriana in Tivoli, in collaboration with the director and the Archaeological Superintendence of Lazio, presented during a recent exhibition in Florence¹⁰.

The virtual reality systems can help the representation of spaces, supporting users for the study and development of simplified models of the environment thanks to automated systems that, starting from simple series of photographs, are able to process and automatically create highly descriptive three-dimensional models¹¹.

The 'Michelangelo Project' is a research project aiming at creating 3D models of the architectures by Michelangelo in Florence by means of topographic and laser scanner survey.

The main purpose is the updating of the documentation, dissemination and enhancement of these works in preparation for the forthcoming centenary of Michelangelo. The project, started in 2003 with the University of Ferrara¹², was divided into annual surveying campaigns and is currently developing and disseminating the initial results.

CONCLUSIONS

Based on the experience carried out in this specific field, operational protocols could be prepared, considering the complexity of the problem to define clearly even at a methodological level, because of continuous innovation offered by digital devices. However it could be important to use a reference methodology at an interdisciplinary level, shared with other fields and approved by UNESCO.

Recent developments of legislation for the protection create buffer zones to protect the sites, instead of the past concept to simply define the boundaries of the territories of Heritage List. These buffer zones are intended to reduce negative environmental or human influences, widening these areas

more than before and including natural or cultural territories of minor interest to create an setting of the World Heritage protected.

The importance of buffer zones consists of the necessary protective measures, which define a new concept of preservation for each site, depending on the peculiar aspects of every area.

Referential quality standards, concerning both protected complexes and areas included in the lists of heritage, and buffer zones of these sites, are present in the management plans of the sites.

Developments and dissemination of innovative IT solutions for cultural heritage, its preservation and maintenance are used to document works of cultural heritage and ensure its management as well as its aware and proper use.

We are moving towards the integration of knowledge and existing structures (for example, the information systems of public and private preservation institutions, research centres, museums, etc.) and therefore the disciplinary field of Drawing can have a more and more relevant role.

NOTES

¹ The Joint Laboratory of the University of Florence Landscape Survey & Design was founded in 2009 for applications and the development of technology related to the drawing and survey of architecture, landscape and urban areas.

Components, University of Florence:

Department of Architecture - DIDA

Department of Agricultural Food Production and the Environment - DiSPAA

Component, University of Pavia:

Department of Civil Engineering and Architecture - DiCAr

External partners companies:

Piacenti Srl - Restoration Center (PO)

Digitarca snc., (BA).

The research group is constituted by professors Stefano Bertocci (DIDA), Rizio Tiberi (DiSPAA), Sandro Parrinello (Dicar), and researchers Giovanni Pancani, Giovanni Minutoli, Andrea Pagano, Matteo Pasquini, Graziella Del Duca, Sara Porzilli, Francesca Picchio and Sara Bua.

² Laboratory of Surveying LRA offers students services Surveying the urban scale and architectural; the laboratory is able to offer services on the design of the 3D laser scanner survey, data acquisition and recording of the vector database acquired. The products supplied will configure as point clouds recorded. The Laboratory of survey is also proposed as teaching structure of specialist level offering courses aimed at 'learning methodologies through specific training courses: short courses, seminars, training courses and workshops, aimed

at acquiring specific skills in the field of digital survey. Partnerships: CyArk (USA); SINECO (ITA), Microgeo srl, (ITA). <http://www.dida.unifi.it/vp-206-laboratorio-di-rilievo-dell-architettura.html>

³ List of UNESCO sites surveyed in 9 countries (17 campaigns in protected sites). Italy: the historical centre of Florence (1982), Piazza del Duomo in Pisa (1987), Hadrian's Villa in Tivoli (1998), Mantua (2008), Medici Villas and Gardens of Tuscany (2013). Israel: Masada (2001). Jordan: Petra (1985). Cuba: Castle of San Pedro de la Roca in Santiago (1997), Old Havana and its fortifications (1982). China: Great Wall of China. Panama, Portobello and San Lorenzo (1980). Russia: St. Petersburg's historic centre and its monuments (1990), Pogost of Kizji (1990), Veliky Novgorod (1992), Kazan Kremlin (2000). United States and Puerto Rico: Fortaleza San Juan, Puerto Rico (2011). Iran: Pasargadae (2012).

⁴ There are many rules in the field of international legislation preserving cultural and architectural Heritage. International treaty on 16/11/1972; Law n. 184, 6/04/1972; *Convenzione per la Salvaguardia dei Beni Culturali Immateriali*, approved on 17/10/2003; *Convenzione per la protezione e la promozione delle espressioni della Diversità culturale* approved on 20/10/2005. In Italian legislation: *Decreto Legislativo* n. 42, 22/01/2004 (in particular art. 133 and 143); Law n. 77, 20/02/2006, *Misure speciali di tutela e fruizione dei siti italiani di interesse culturale, paesaggistico e ambientale, inseriti nella lista del patrimonio mondiale, posti sotto la tutela dell'UNESCO*.

⁵ A Management Plan for a Unesco Heritage List

defines the rules to protect and enhance a protected site. The analysis considers: territorial and city plan legislation, social and touristic development, lists of heritage. The second part consists in the Management Plan: cultural promotion, planning for preservation, legislation for management (restoration, landscape protection and enhancement).

⁶ For the data management from different devices it is important to verify the different sources related to software with different extensions. The software are chosen according to two main requirements: interaction with different data, elaboration on collected data. For this reason it is necessary to have equipment such as workstations and hard disk storage, in order to store correctly the collected material. The daily backup should be done both on a workstation and on removable media like hard drive, in order to reduce the possibility of data loss on technological support.

⁷ See Bertocci-Bini 2004; Bertocci-Bini 2009, 43-61.

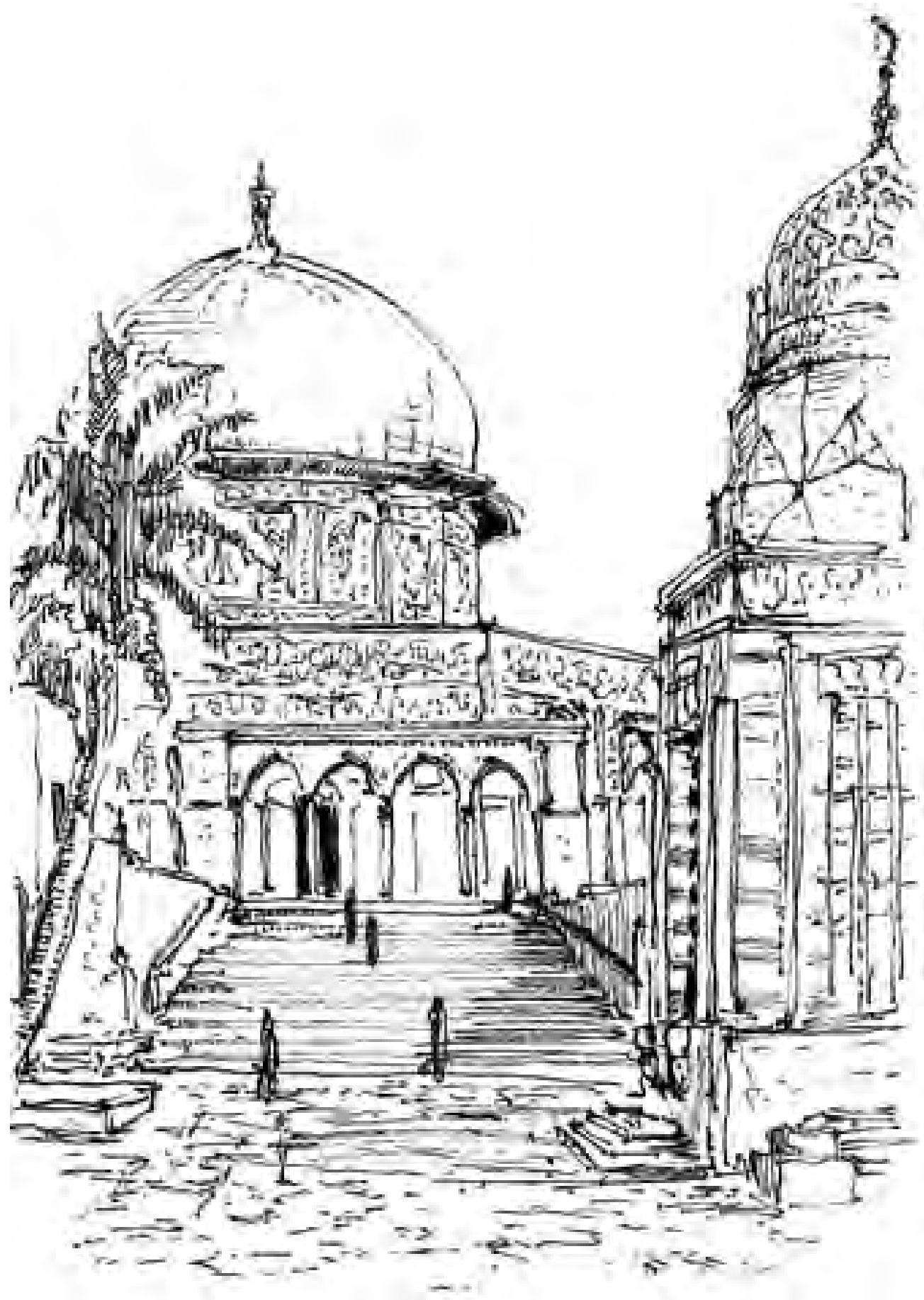
⁸ See Bertocci-Parrinello-Vital 2013.

⁹ See Bertocci-Bini 2012.

¹⁰ The exhibition in Florence entitled *UNESCO archaeological sites: some experience of survey and investigation*, held in October, 2013, by S. Bertocci, showed the results of researches carried out in Florence, in the church of San Pier Scheraggio site, part of the Uffizi Museum, Hadrian's Villa in Tivoli, Masada in Israel and Palmyra in Syria.

¹¹ *Image-based* is the term used to define the models directly generated by two-dimensional images.

¹² Bertocci-Puma-Balzani 2007.



Methodologies for the documentation of the image of the architectural structures

Sandro Parrinello

DICAr – Department of Civil Engineering and Architecture, University of Pavia

INTRODUCTION

As a recapitulation of the experiences of documentation presented in this catalog, it seems appropriate to make some remarks on the state-of-the-art methods for architectural survey that are now in the research project. In particular when we talk about a UNESCO site we refer to a site that collects, or is able to gather itself, the qualities that identify a specific context or a territorial region, in relation to a specific historical period.¹ There are such specific qualities, full of meaning, that evoke aspects of a more general nature in relation to a cultural context. Therefore it is a place, in which can be perceived a cultural dimension that goes beyond the single building phenomenon. For these reasons, the researches that focus on UNESCO sites are not only aimed to the collection of data related to

a specific artifact, but always require an extended vision to determine instruments of synthesis able to explain considerable complexities.

At the management level the protection of UNESCO implies the assumption of territorial planning rules that have, as a natural consequence, a need for accurate documentation systems designed to plan the development and maintenance of certain specific properties of the site, and thus require the construction of synthesis systems such as an accurate drawing of the current state. An overview that gives the essential basics for the project, the instruments through which its complexity can be read in a simplified form and to give a planning sense and an orientation to protection and development.



Opposite page: drawing for the study of the Dome of the Rock in Jerusalem. Above: a drawing of the Serapeum at Hadrian's Villa, Tivoli, Italy.

THE CRITICAL TRANSPOSITION OF THE ARCHITECTURAL ORGANISM IN ARCHITECTURAL DRAWING

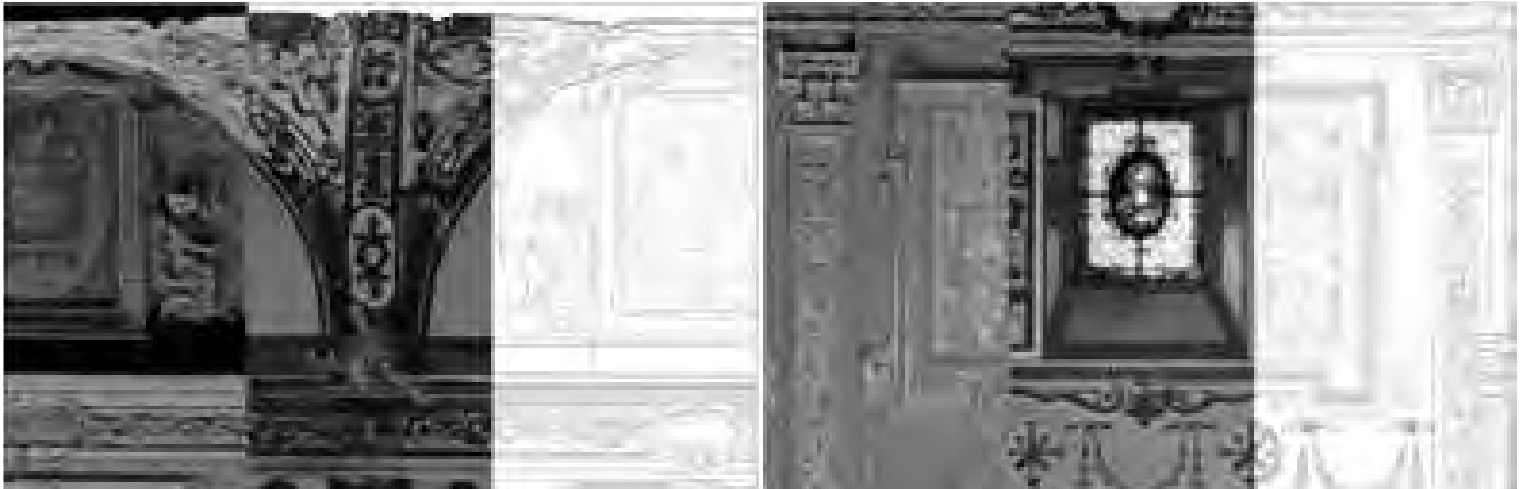
The notion of measurement is expressed in the concept of law and order, in the dualism between human and natural, that could not find a more appropriate moment for deserving a deep reflection, if not within the research activities made for the development of measurement systems of a place. Determine the architectural image, the quality of the masonry and of each lived environment, through the execution of a drawing, allow to order, in a physiological map of the building, the representation of quantitative and qualitative information of space and place. The drawing expresses the relationships that determine the architectural structure through the use of a hierarchy of signs that, orientating the reading of the graphic text, highlight a structure to which it is necessary to refer when you intend to deal with a critical analysis related to the interpretation of the context. When the drawing is the result of a survey

procedure on artificial place, the data obtained by the investigation are collected and processed by the surveyor that sum to these aspects of the order the requirement for a metric dimensional control. This information, full filled with meaning, is then used as the container of the data acquired through the various researches.²

A territory, a town, an architecture and even a small object, are all very complex. Their quality can be related to shape, size, color, structure that keeps them standing, sensations felt in living them, events that have affected them over time, activities that can be leaded with or inside them... the list can continue.

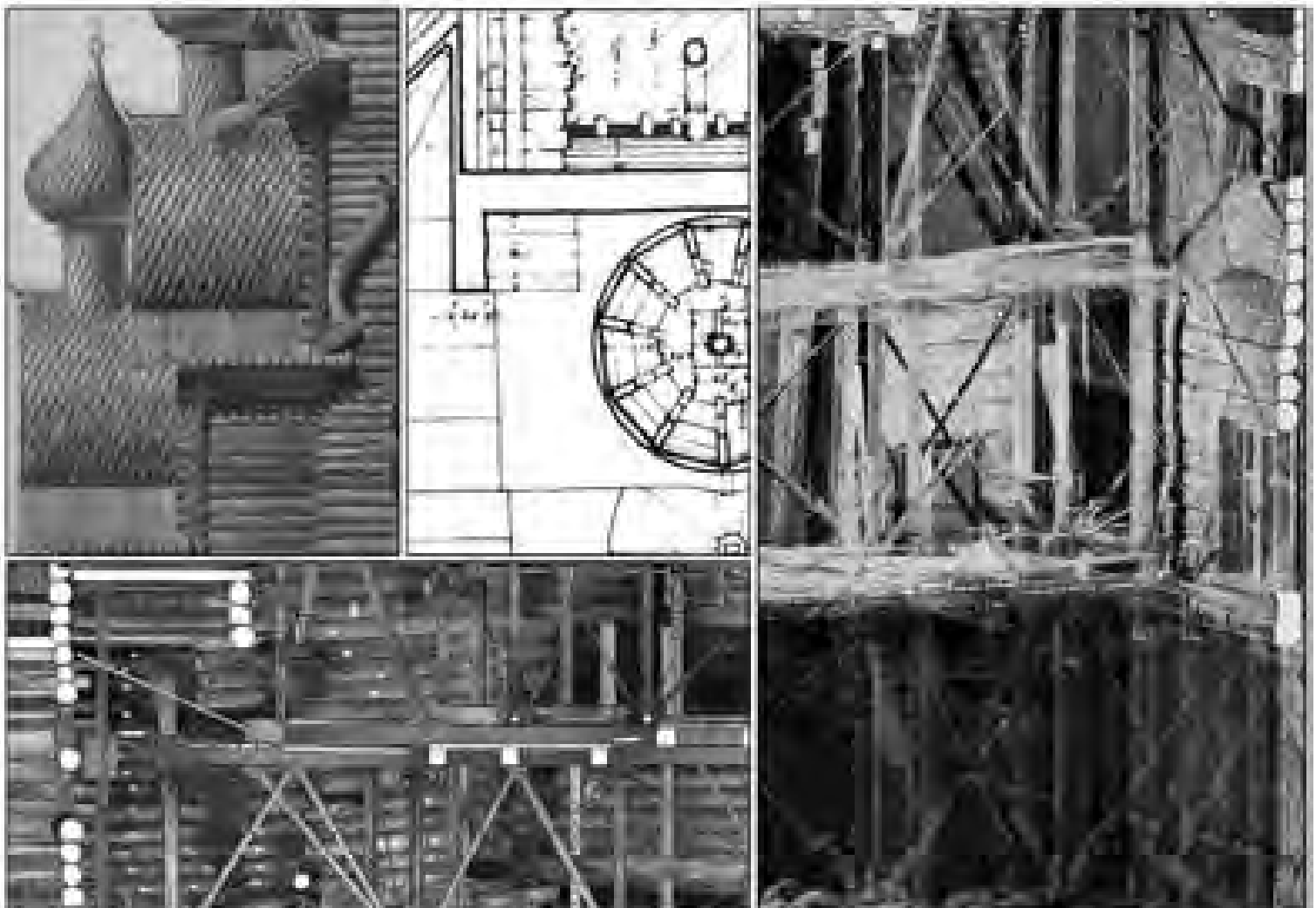
Therefore, in making a survey, it is necessary to identify and define only certain qualities of the objects. It would be impossible, in fact, to reproduce all the qualities, unless realizing a copy of the object, identical to the original. So a survey always requires the analysis of the different qualities of an object, the selection of those considered signifi-





Previous page: The architectural survey for the structural analysis of a wooden church in Karelia, Russia. The complexity of the architectural organism has been assimilated by the survey and, through 3D modeling programs, each wooden element is reconstructed in a virtual space. Above: from laser scanner survey, to the drawing of stucco decorations in the church of the her-

mitage of Camaldoli (Arezzo, Italy). Below: historical surveys of the Church of the Transfiguration of the Kizhi Pogost (Karelia, Russia) in comparison with the point cloud of the laser scanner survey and the section drawn to the study of the structural condition of the church. In these examples, the digital survey solves problems of morphological and spatial complexity.



cant, and finally the synthesis of all of them made through a graphic model.

We can then have a survey for historical knowledge, a survey for the restoration, a survey for archaeological documentation, a survey for cataloging, a survey for the formal and dimensional knowledge and, finally, an experimental survey aimed to the didactic activity, or rather the comprehension of instruments and methods. Currently, instruments and methods of survey and representation have become more scientific than ever before (thanks to the metric unification, to more refined instruments, to a greater sharing of operational methods and graphical techniques). But even if from formal copies of the monuments, typical of

the nineteenth-century Academy, the representation goes to a more scientific form, a survey will never be neutral, because the technique can not be reduced to a mechanical process but always involves formal and cultural determinations.

From the epistemological point of view, a survey is based on mimesis and measure. Mimesis is the relationship between an object and his representation, it is what allows you to recognize a drawing from a real object, and vice versa. Any kind of survey but also any kind of draw (even a freehand draw), always requires a preventive measure. Measuring means choosing and judging the qualities by assigning to them a value.

Below: drawing “wireframe” of the internal walls of the church of the hermitage of Camaldoli (Arezzo, Italy). The complexity of the ornamental system must be, in some way, transmitted to the architectural drawing. Without losing reliability the architectural drawing must be able to express the deformations and individual imperfections, especially geometrically that the architectural element presents.



COMPARING DIGITAL SURVEY TECHNOLOGIES

The constant evolution of techniques for surveying and 3D modeling based on sensors and the development of ever more efficient systems for visualization of digital data highlight the added value of the use of these methods in the context of architectural documentation.

The technological solutions nowadays at disposal of the architectural survey offer numerous opportunities for conducting documentation projects in the field of Cultural Heritage, both as regards the time of primary survey, or rather the phase of metric data acquisition, and as regards the question of representation for objects of archaeological, artistic, architectural interest.

It is an integrated and multi-disciplinary approach of techniques and technologies that make up many different approaches to determine the multi-scale surveys, which place a phenomenon in relation with its context, where all the data and results of a survey converge into a single and well defined reference system.

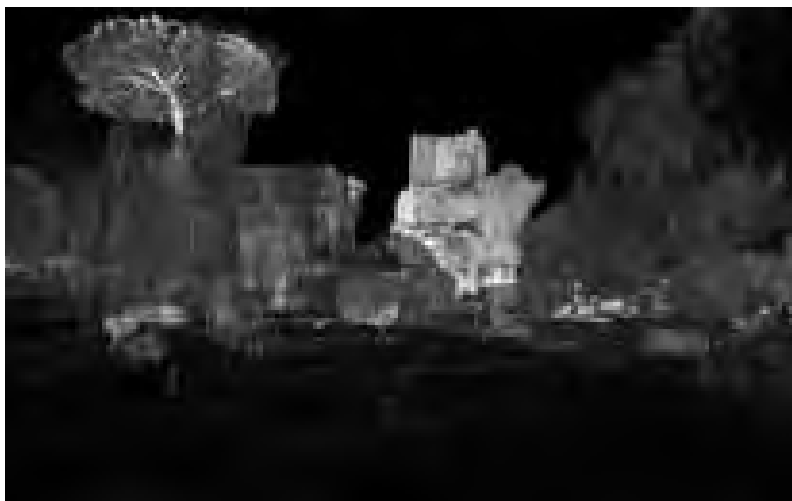
The new digital techniques and technologies offer the possibility of obtaining new products not only from survey activities, but also in the representation and in the visualization, with the purpose of having an accurate metric description of the territory, structures, buildings and artifacts.³ They constitute powerful instruments for the analysis of objects in support of reconstruction and restoration activities. The acquisition and the processing of data must be made following appropriate methodology, taking into consideration the characteristics of each technique both in terms of inherent capabilities, such as precision, accuracy and format of the data, both for the purpose of mutual integration, with the aim to incorporate all the products in a common database, useful for many applications, divulgation, documentation, studies of stability of structures, etc.

The first step is usually the definition of reference points or reference net of markers located in the area of interest; this, generally implies the adoption of space geodesy, for example for connection to the IGS net of permanent stations in order to achieve the absolute georeferencing of the site, in the case local geodetic points or known data in this regard do not exist, as often happens. The GPS system can also be used in kinematic mode for the description of the morphology of the area and the survey of the structures, sometimes coupled with other techniques, such as classical topographic surveying with Total Station and aerial photogrammetry from low altitude, even with the use of non-conventional platforms, and the terrestrial one. In any case the results are obtained in the same reference system. The same points already collected can be used for georeferenc-



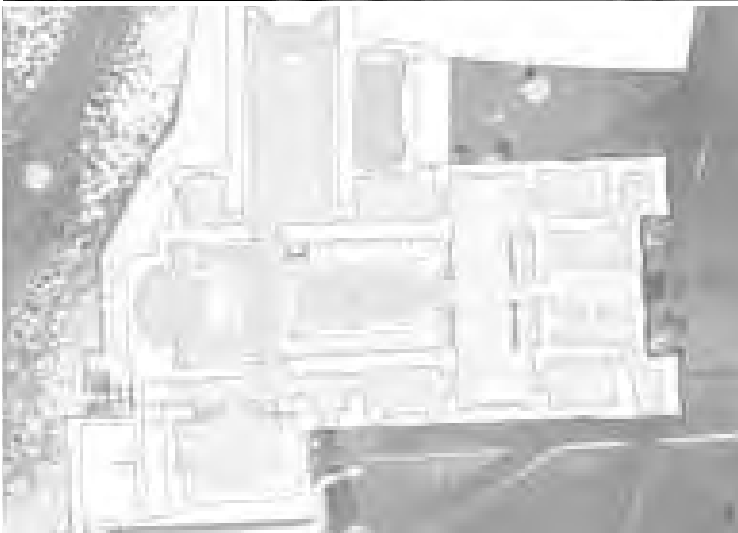
Activities of the architectural survey in the field using laser scanners, topographic total stations, or GPS systems: the objective is to determine framing systems through the creation of auxiliary structures for the control of the error and for the acquisition of general measures.







Some examples of three-dimensional databases; the point clouds acquired by laser scanner survey of complex systems: the archaeological site of Hadrian's Villa in Tivoli (Rome, Italy) examples of surveys for urban clusters of L'Aquila (Italy); and the monastery of Camaldoli (Arezzo, Italy). Through the clouds of points can be read and interpret the morphologies of the environment and the volumetric composition of space.



ing of satellite images, which are useful for a description of the surrounding area and as a base to merge and overlap all surveys and other existing data, as well as other studies, such as classifications and thematic interpretations.

Topographic classics surveys, terrestrial laser scanning and close-range photogrammetry are used at the scale of the site for the survey of elements and structures; all the methodologies require the definition of the orientation in the common reference system already defined.

Photogrammetry, alone or integrated with the laser scanning, with their products such as orthophotos, the three-dimensional vector restitution and Digital Surface Models with or without the application of textures, are important instruments for the study of visual and structural analysis, for example with the purpose of restoration, combining accurate metric information with a high quality photographic description.⁴

Finally, the knowledge of a site can be facilitated by virtual exploration using visual reality techniques based on photographic data, such as technology QTVR (QuickTime Virtual Reality) or on vector and raster data, such as products in VRML format, considering that this type of products is highly interactive and can easily be made available on the web.

For individual objects, the study can be accomplished using different techniques, depending on the characteristics of shape, dimension and location of the object and the purpose of survey; in this sense the digital photogrammetry is an excellent solution, thanks to its characteristics to realize the survey without contact with the object and in a short time. Now it is also possible the using of low cost digital cameras, which allow the acquisition of a metric data with simplicity, economy and easy handling, although in this case the photogrammetric process becomes more difficult, requiring the use of appropriate algorithms and procedures, especially with regard to the phase of calibration of the camera.

The future of the survey science in the field of Cultural Heritage is probably in a multi disciplinary and multi techniques approach; the fusion of data from different

From the "3D database", consisting of the point cloud laser scanner, the drawing "wire frame" the plan of the complex and treatment with photo-plans for the study of the paving.

techniques (photogrammetry, laser scanner, GPS, remote sensing, ...), allowed firstly by sharing a single reference system, and also allowing the reading and understanding of each object of interest not only in itself, but in the context in which it is located, exploring the possibilities for its study and understanding.

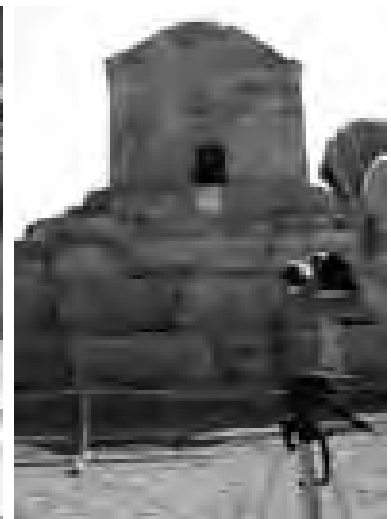
These methodologies lead to the creation of three-dimensional dynamic databases on the heritage, implying the addition of a new informative layer and the subsequent planning of the digital archive capable of taking into account the 3D data for both the geometry and morphology of the acquired object (useful for protection and conservation), as well as real containers of useful information for the management of the site (information turned into restoration and scientific purposes) or for the public dissemination in the museums through virtual reality.

In general, the data are organized in a structure that depends on the more appropriate methodology to solve problems depending on the object to be acquired; they will be divided in source data, such as photographs, laser scanner point clouds, etc., and processed files, such as drawings, recordings of the same point cloud and all that contributes to determine a three-dimensional or multi-dimensional comprehension of the site.

The 3D model is one of the most efficient ways to let understand the spatiality of complex environments that can not be perceived with the eyes nor effectively described by the orthogonal projections.

The possibility of using three-dimensional models also for purposes other than simple documentation and representation, such as for structure evaluation or related to diagnostics of materials and to the state of degradation, opens an important window on the adoption in the *close range* of methods of *data fusion* and image analysis for example related to satellite remote sensing, combining the information given by the sensors operating in the optical field and the one given by others, such as thermo or multispectral cameras, or the instruments for geophysical survey. However, this poses numerous problems both regarding the acquisition, and then the calibration of these sensors, and as regards the treatment

Procedures for data acquisition via camera for the development of systems structure from motion. The aim of these methods is the creation of point clouds. Moments' work during the architectural survey of the wooden villages in Karelia (Russia) and during survey procedures for analysis of urban and monumental complex in Iran. These technologies can also be used to develop general drawings through aerial photography.





3D models and virtual environments realized through methodology structure from motion.



The surveys conducted for the study of the San Lorenzo del Chagres (Colon, Panama) where is possible check the alignment of 3D models from photos with the point cloud topography and the creation of 3D models of Herod's palace at Masada (Israel) with the verification of 3D models comparing the model obtained by structure from motion with the model obtained by laser scanner.

of the data; the possibilities are also valued for applying in this context, issues such as the automatic or semi-automatic interpretation and classification of images and data of other kind. Finally, in addition to these new opportunities, the possibility should not be neglected, certainly aided by digital techniques, to adopt methods for metric recovery purposes of archival photogrammetry, for an objective and rigorous study of the transformations that an object has undergone over time through the use of historical photos, properly calibrated and processed.

GRAPHIC EXPRESSION OF ARCHITECTURAL SURVEY

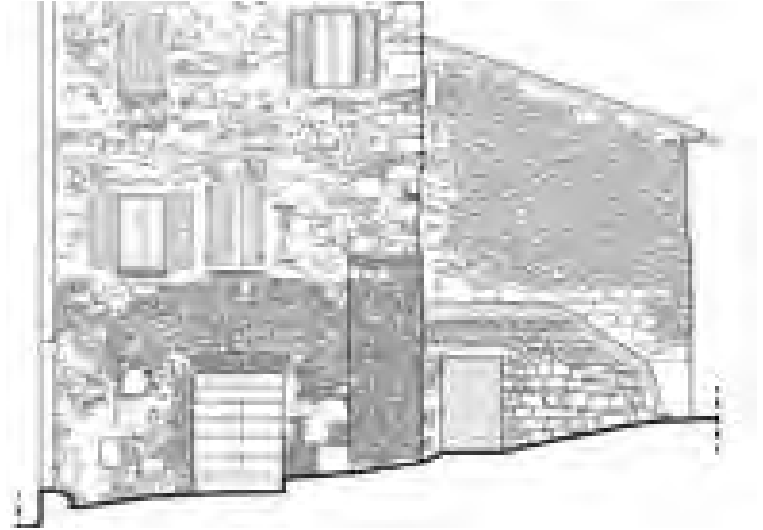
Among the many professionals operating in the cultural heritage field, the drawer is undoubtedly the one who possesses the highest number of cultural tools to express, starting from the image of reality, the signs needed to make the synthesis of a place.

When the documentation drawing interprets a phenomenon which takes place, like the relationship of each element present, whether architectural, historic or cultural, including the surveyor himself with the surroundings and



A village of wooden houses in Russia and a portion of the city (Bethlehem); images of 3D models at the preliminary step of the data processing. The survey was carried out by photo modeling and structure from motion capture.





Drawings wire frame of urban fronts. The quality of the architectural drawing is represented by the individual bricks, the individual stones that make up the facade. Even the trees and natural elements are metrically corrected through the use of laser scanners.

even the territory, it must be clarified, thus providing an interpretative key for defining a relevant investigative structure for analysing and recounting the place. In general, this relationship is defined by the term landscape. The survey is an indispensable process in order to know and understand the architecture of a building in its dimensional, spatial, constructive, historical and material components. The knowledge and understanding of its qualities are primarily evaluated by means of graphic models.

In this regard, the school that in the last twenty years has been operating in Florence to study the expressive qualities of architectural drawings aimed at monuments survey, has been focusing on the definition of drawing interpretative systems, as it considers drawing an actual container of significant signs organized in precisely defined theoretical models.

Architectural drawing is coded and normed in order to uniform the expressive language so as to obtain an interpretative model of buildings. Such model – which is formally called the structure of a place – becomes readable in technical works through the composition of the descriptive system, through the attention to details and through the variation of particulars that the quality of materials, constructive systems and architectural components generally bring to the real space.

As a critical reading of happenings, drawing is composed of sign, graphic style, symbol and gesture to express the peculiarities and complexities that characterize architecture, sometimes through similarity to reality, sometimes through a more complex abstraction that shows more explicitly the drawer's interpretative synthesis. The consid-

erations suggested in this article aim at evaluate not only the effectiveness but also the actuality and necessities that have been lately required of the architectural representation and drawing. Such considerations take into account the growing number of applications that regard the interaction between drawings and models and try to understand the rules that the limit represent in those practices of a project.

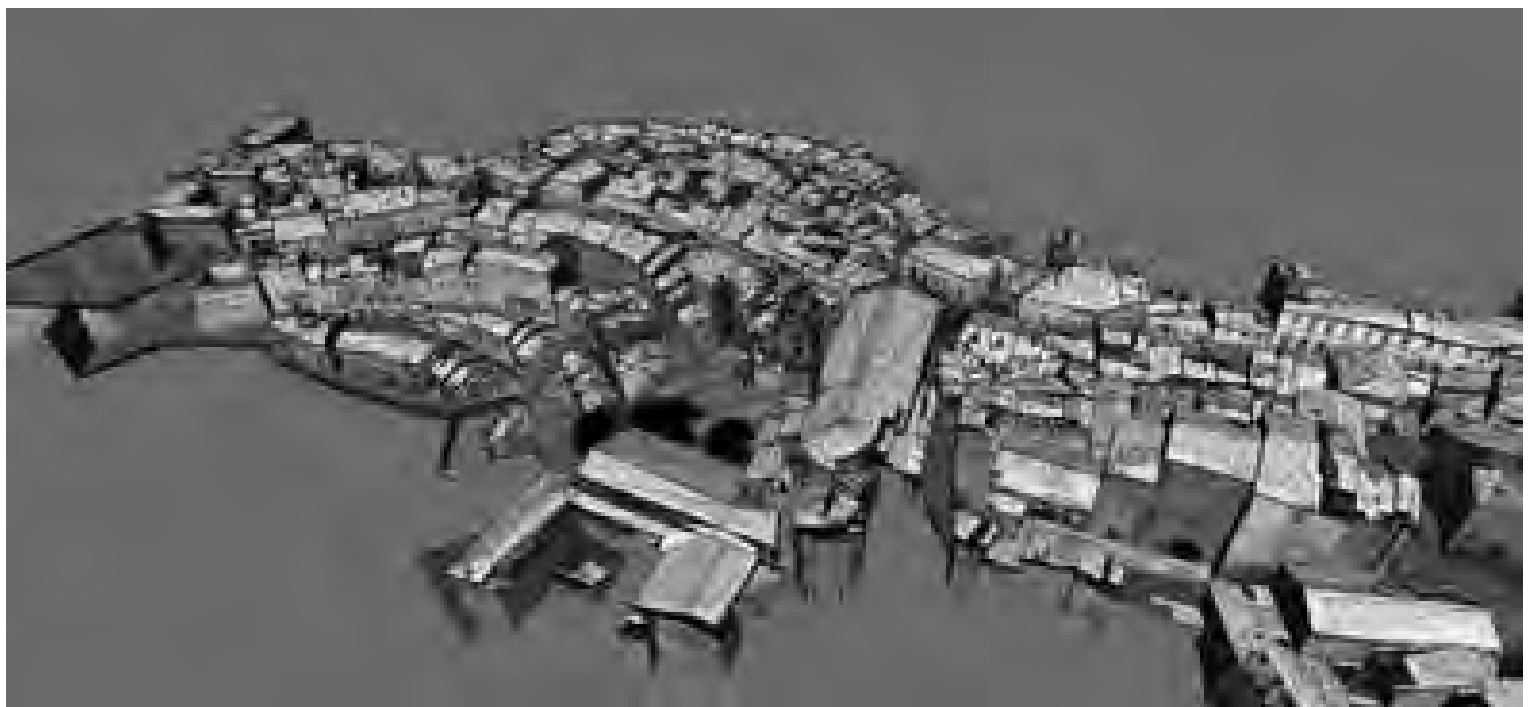
Drawing entails the definition of limits, the development of readings that ordinate space through mental synthesis. Such synthesis studies, simplifies and understands objects in relation to the context and re-presents them in their essential form, so as to bring to light characteristics that can lead to a discussion that starts in the drawing itself.

Every sign on the sheet is a limit that divides empty spaces of the drawing, which is followed by an attribution of strengths, weights and rhythms that animate the void space of the graphic board in the mind of those observing the representation. In the representation of what is perceived there are also limits that go beyond the mere graphic style, limits that can not be assumed by the proportional relations in the context of the sheet; these limits relate to absence, to the lack of something. Such marks can explicate a perceptive restriction of the analysis in reading of the text. Drawing, in the act of interpreting an object, can not avoid an approximation deficit that highlights the limit of the image trying to reach reality. Such deficit shows the perceptive and expressive limit of the analysis, at least from a graphic standpoint.

In observing a drawing, the attention focuses on the codification of the signs within the sheet, on recognition and interpre-



A conceptual 3D model developed for the study of urban form in the historic center of Odessa (Ukraine) and other 3D models from architectural scale, such as that for the chapels around the monastery of Vallombrosa (Italy) and the historic center of Montepulciano (Italy). The ability to manipulate the virtual space and create instruments in which to live an immersive experience in the landscape increases the potential of these systems of analysis. A possibility offered by these models is to become instruments of remote fruition of space, through access portals such as web or platforms for the development of tourism or for the management of historical and cultural heritage.





tation, in the attempt to put the information on the sheet into a logical structure that can clarify (from the observer's viewpoint) the consequentiality of descriptions upon the represented system. Such mental order will try to answer a series of questions, starting from the simplest ones, which regard the general subject of the drawing and the answers to which can be even found in the title. According to the imagination of the title itself, the observer will then try to collect general impressions of the drawn image, explicating the relations between what is imagined and what is currently being observed. This initial difference between reality and imagination brings about a first evaluation of the graphic system, which is followed by a series of expectations that look for confirmation in the context of the drawing itself – always by means of a comparison

with the ideal image. When architecture is the subject, the observer will most probably carry out such in-depth analysis spiraling from the overall picture to particulars. Firstly, overview and orientation, secondly the relation to the context and the specifications describing the architectural system 'from a distance'; then, through the clarification of plans and elevations, the search for an order of the spaces in the drawing becomes an activity that implies the evaluation of the entire architectural system.

In this journey towards the understanding of the text, the feeling of immersion derived from suggestion entails the illusion of being within the represented space, where the references to the real world will be the basis to identify and translate the graphic language.⁵



From the 3D model of the city you can check out environmental sections and metric information about the conditions of space and character of the urban system. Through virtual simulation it is possible to observe the city from many angles and, using a 3D model metrically reliable, it is possible to conduct environmental impact assessments regarding the inclusion of new urban design projects.

The more the drawing is able to represent an aspect of reality – and hence lessen the degree of abstraction – the more it will become easy to understand. A realistic, almost photographic drawing with ‘illusionistic’ purposes will lead to an immediate reading, which will cause in the observer a higher degree of evocation of the considered reality. In the process of comparing imagination and representation there is a natural search for naturalistic appearance, not just of the image but also of the codes, of the appearance to which we are used in real life. An easy comprehension of the visual message, as well as the subsequent visual emotion, depend on the enhancement of the exterior aspects and essential parameters of the image. Conversely, a drawing characterized by a strong symbolical connota-

tion – which considers one or many aspects of reality and translates them graphically through a specific language – demands from the observer the ability to interpret specific signs and symbols, accessible only by someone who can decode those signs and symbols; the meaning, message and aim of the drawing itself become clear only through symbols and graphic conventions that prevail, especially in traditional technical drawing, on the search for natural appearance and illusion.

In general, this diversity depends on a selective process that allows the drawer to highlight the significant characteristics of a subject: this is probably the most interesting, formative and meaningful aspect of drawing, and it applies to both real-life and project drawing. It is the selection



of the characteristic data that can define an architectural particular, an urban context or a landscape. To apply such selection it is necessary to have a direct contact with the architecture or landscape that has to be graphically expressed, as well as it is necessary to choose a sign system that can translate the elements of reality in an image, to examine shapes, proportions, position, light and every other element, in order to reach a highly-characterized graphic synthesis, more or less abstract.

As a matter of fact, the term 'abstraction' signifies the mental process through which a group of objects is replaced by a more generic concept, which describes the objects on the basis of their common qualities; through such mental process we detach and extract one or more aspects from a visually perceived whole. What then happens on a graphic level is a stylization and geometrization of what is perceived. It's a process of fantasy where, by association of forms and concepts, qualities that belong to distinct elements are matched with each other. The landscape image – hereby meaning a wide range of ideal and metaphorical perspectives – becomes a 'mental place', a way of thinking reality and relinquishing a synthesis from above, a representation of something that is non-representable because it can never be definable-measurable-quantifiable, and becomes an expression of the undeniable presence of the horizon, a metaphor or thinking space as a group of relationships and interactions that will never be steadily definable, never univocally understandable, in a strategy of thinking that always leaves space for creative processes and continuous re-problematization of certainties.⁶

Hence, drawing is a narration of what is represented that brings about two levels of abstraction: the first depending on the drawer, who simplifies and characterizes certain elements; the second depending on the observer, who is asked to read the drawer's critical contribution expressed in graphic and proportional rules.

Thereof, limit is always intrinsic in every drawing as a forming element in the activity of reading space. Quoting Giorgio Bassani, in order to draw well it is necessary to dismount the world, re-build it piece after piece with infinite patience. In this regard, tearing apart equals discretisation, the reduction of the continuity of space to discrete elements, hence to the definition, in the place's structure, of the levels of depth of the graphic analysis necessary to describe and clarify the qualities of the architectural system. Drawing always has an aim itself: drawing for the projects, for the documentation, for the valorization... the name itself implies thinking and designing the image not only from a scenographic point of view. Drawing can be

linked to descriptive systems that use different rules, thus a drawing can be realized by means of informatic tools to obtain multiple aspects that will be useful to many of the functions of the process identified during the definition of the objectives. Rather than a simple image representing a condition, drawing are progressively becoming an actual container of information. If this has always been true, today the acknowledgment of such multiplicity and multidimensionality of the graphic form compels the drawer to define projects and complex development methodologies, so that the drawing can explicate the possible interactions with the diverse interpretations for which a schedule and a drawing have been required in the first place.

Thus, if a drawing is a container of multiple containers, corresponding to diverse applications but also to diverse emotional implications and suggestions, the vertical limit –

the graphic deepening of the areas of interests of a scene – becomes the object of investigation and consideration. The aesthetic limit between realistic representation and abstract synthesis will have to be formulated so as to allow the representation of the many fragments composing the scene and the architectural drawing, and it will have to describe in details the real state of places to fulfil its documentary purposes. The qualities of a wall will depend on how it relates with the surroundings, on what it runs around and what it hides, but also by its building materials, to the point where each of its bricks requires a description as it contributes, with its flaws and imprecisions, to characterise the elevation's surface. It soon becomes clear that between the ideal geometrical condition, the formal and project model and reality there is a great variation in the qualities depending on the constructive method and on the extent of



Views of 3D models: virtual urban landscapes (opposite page), and the inside of the Church of the Monastery of Camaldoli (Above). The spatial complexity of the volumes and the quality of the materials make the models the effects of hyper reality.

the building's conservation and decay. Materials warp, they change in appearance almost completely, their geometry changes because of a simple inflexion or a coat that can entirely alter the image of the architectural experience.

A drawing has to collect all this information, especially now that computer graphics allow to navigate within infinite vectorial environments, as well as to ordinate and code the description of a virtual space in order to make it as similar as possible to reality, limiting any unnecessary approximation.

In the past, such approximations were almost necessary, not only to confine the drawing in a strictly free-hand production process – in which qualifying a critical aspect of the interpretative procedures of buildings became necessary – but also because the typologic conception of architecture required a formal rationalisation of the interpretations, to which followed a drawing of the type.

This is a simplification where the necessity to describe the specific qualities of an architectural phenomenon is replaced by abstractions, aimed at highlighting those characteristics that allow to understand an object in a whole. However, especially when we consider case studies that are not focused on the same space but on a vast territorial quality, a type hardly possesses univocal characterising aspects. It is hard to conceive a typology that could summarise the whole architectural phenomenon, which for its complex nature is characterised by different materials, building technologies, distributional systems, orientation and position within a space. The architectural drawing hence tries to express the variety of the architectural system itself, of the building model and of the landscape installation, even when the planning-oriented synthesis process brings certain architectural qualities back to pre ordered schemes of typological nature, as it normally happens.

It now becomes clear that the core problem of drawing is how to interpret architecture to represent it correctly, and also which thematic reading is appropriate for a drawing in order to make it as expressive as possible within its context. I believe that one of the main problems for drawers is to stop limiting themselves to represent architecture (which is not a theatrical piece; architecture is self-representative and can only be interpreted) and focus on the real problems of architecture, which can not be left only to the management of monuments superintendents or to some extravagant project designers.

During the years spent researching – mostly out of Italy – I have had the possibility to compare the way of thinking architectural representation developed within the Florentine school with other practices of intervention applied by local superintendents and by institutions for Heritage protection

in Central and South America as well as in many regions of Russia and Asia. Every time I had to read a technical report about an architecture or a monument I needed to understand what the surveyor's interpretative purpose was, because the surveyor was never able to collect a drawing that could summarise the context completely. In many conferences, especially in Russia, it was common practice to praise ancient drawings, hand-made surveys collected centuries ago but far more descriptive than technical outputs realised by means of a computer. It was not just the aesthetic aspect of graphic representation that was being questioned, but also the complete lack of reliability, evident even at a first reading. In most cases, those drawings roughly represented an ideal condition of the architecture and were far from reporting also the object's imperfections and variations. What they actually failed to convey was the research project behind them, the understanding that the drawing is in fact a container of several possibilities that guide the analysis, which is aimed at diverse projects. If a drawing does not have a specific purpose that regulates it, not only will it not describe aspects 'suitable' for the research, but it will also be unable to meet the projects' requirements in terms of environmental description – thus, it will be useless.

It may be a personal fixation, but I am convinced that the task of guarding architectures has to be left to those who know how to observe. Nobody can observe with the same attention of a drawer who, by practising his 'art', has developed an attention to details that others seldom possess. In the past, Italian cities had what were called 'commissioni d'ornato' ('decoration commissions'), mostly composed by artists and people who supposedly had 'good taste' (a rarity, nowadays), which oversaw public ornaments and 'decorum'. Today's risk is that a careless practice of drawing could lead to losing control over the architectural phenomenon at all levels of heritage planning and management.

In Karelia, Russia, the Federal Administration of Kizhi Museum tackles these problems on a daily basis, sometimes adopting managerial solutions that seem absurd, precisely because they lack scientific groundings that can be verified by means of drawings. From landscape management to the restoration of its monuments – which I would rather define as brutal and false reconstruction, in spite of UNESCO's directives – every activity is undertaken without consideration of the architectural system's qualities and eventually ends, after the so-called maintenance, in a replacement of the values carried by the place's qualities and characteristics.

After a long debate on the most appropriate restoration methodologies, the Church of Transfiguration was uplifted, tore apart and rebuilt in parts, thus completely subverted in its geometry, because the new building process had not been based upon a reliable survey that would take into account the variations of each wooden trunk. Wood architecture is probably one of the hardest and most complex to study because of the material's nature, of its plastic conditions, as well as of building technologies characterised by complex internal structures. It is a pity that, in certain cultural contexts, such architectures must be lost because of an utter incapability of understanding the right dynamics of intervention upon the historical heritage.

Many countries show an in-depth knowledge of the theoretical problematics related to preservation (besides Russia, many Central American countries) but they completely lack practical experience. Thus, a general knowledge of proper restoration is applied and used together with entirely-individual practices and initiatives, which are far from being correct. In many cases, such misunderstandings derive from the incapability to operate correct surveys. In addition, there is a wrongful trust in new technologies. A laser scanner is not enough to realise a correct, reliable and useful survey for monument preservation. The post-production of point clouds is by far the most important stage and it requires experience and a deep critical understanding of the whole

project for which the survey has been taken. Eventually, even when such tools are employed, it is always the drawing – the interpretation of point clouds to define the bi-dimensional output – that qualifies the whole survey process and defines the correctness of operations.

Survey is the first step of any kind of intervention. When survey does not try to integrate data from additional activities and when it is not aimed at collecting multidisciplinary activities, the project – any project – will inevitably carry a dramatic fracture within itself, given by the lack of confrontation and comparison.

When survey is entirely lacking, so are the tools for a knowledge of historical architecture and the latter is rapidly wiped out by the great cultural renovation that dictates architectural models unrelated to the context. This is true for almost all historical centres in Russia – with the exception of Saint Petersburg – for many Caucasian and Eastern European countries and, in general, for those places where the analysis of architectural models could still bring to light new pieces of buried history, only readable in the arrangement of some stone carrying traces of cultures, commercial routes and past influences. This is the importance of survey and of the preservation of architecture, which is not simply a practice to gain knowledge, to narrate and organise data, but may also be the only hope we have not to eradicate from our planet those coats, colours and details that express the greatness of time through their imperfections.

NOTES

¹ For a general overview on the research activities conducted by the Italian research institutes on UNESCO sites Cfr. AAAntonio Conte, Monica Filippa. *Patrimoni e Siti UNESCO. Memoria, misura e armonia*, Gangemi Editore, ISBN: 9788849227284, Matera, 24-26 Ottobre 2013. For a more general treatise about the experiences of research in the documentation, not necessarily related to the UNESCO sites, it is possible to consult the catalogue of Italian research edited by Paolo Giandebiaggi, Chiara Vernizzi. *Italian Survey & International Experience*, Gangemi Editore, ISBN: 9788849229158, Parma, 18-20 settembre 2014.

² The drawing, as a product of a reading of the space, is in itself critically defined and built. In signs and in the logic of the drawing is possible to establish connection of relations, structures that define the connection between the data. The meta data, with the specific group forms, in this case graphics, animate the matrix of information that, in

the digital domain, give meaning and significance to the virtual space.

³ The architectural survey today, means specially with the spread of the practice of study of cultural heritage of the Anglo-Saxon, may lead to two general results: the first concerns the creation of drawings and tools to intervene on architectural work, survey for the restoration or conservation, drawings that require great precision to solve practical problems concerning operational protocols of intervention; the second type of result is limited to the production of three-dimensional images for the digitization of the architectural system, for virtualization of the site for the purpose of creating enhancement tools. In the second case the levels of precision and accuracy are less important because the virtual object will be received “almost” like a video game.

⁴ For a reflection on the development of detection techniques using structure from motion techniques you can compare: Sandro Parrinello, Francesca Picchio (2013). *Dalla fotografia digitale al modello 3D dell'architettura storica*. DISEGNARE CON...,

vol. 6, p. 1-14, ISSN: 1828-5961, doi: 10.6092/issn.1828-5961/3870.

⁵ For a discussion on the value of the “special design” in the graphic restitution of architectural survey, also in view of the different types of architectural surveys and objects of study cfr. Sandro Parrinello (2012). *Il disegno dell'imperfetto. Esigenze descrittive per l'analisi architettonica*. In: APEGA_Asociación de profesores de Expresión Gráfica Aplicada a la Edificación. Investigación Gráfica Expresión Arquitectónica. vol. 1, p. 375-381, Editorial Universitat Politècnica de València, ISBN: 9788483639641, Valencia, 29, 30 de noviembre y 1 de diciembre de 2012.

⁶ The processing mode of the “graphic thought”, in relation to the production of drawings and analysis on the architecture, as well as the study of how to interface between artist and mental landscape, are addressed in the book: Sandro Parrinello (2013). *Disegnare il paesaggio. Esperienze di analisi e letture grafiche dei luoghi*. vol. 1, p. 1-304, Firenze:Edifir, ISBN: 9788879706179.

Research Experiences



Digital Survey for the tomb of Ciro the Great in Pasargadae



■ SCIENTIFIC BOARD OF THE PROJECT

STEFANO BERTOCCHI, SANDRO PARRINELLO

■ TECHNICAL COORDINATOR OF THE PROJECT

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UNIVERSITY OF FLORENCE; UNIVERSITY OF PAVIA; SCHOOL OF ARCHITECTURE, FACULTY OF ARCHITECTURE, COLLEGE OF FINE ARTS, UNIVERSITY OF TEHRAN, IRAN. FACULTY OF ARCHITECTURE, COLLEGE OF FINE ARTS, UNIVERSITY OF TEHRAN, IRAN.

■ WHERE AND WHEN

PASARGADAЕ AND NAQSH-E ROSTAM, IRAN, 2013

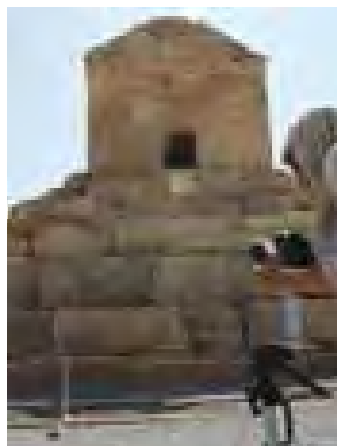
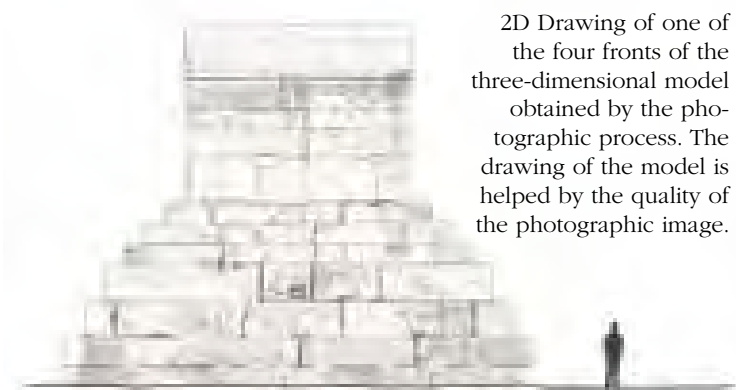
■ AIM OF THE PROJECT

The fast survey work carried out in the archaeological site of Pasargadae aims to the realization of 3D models of the most famous monument of the site, the tomb of Cyrus the Great, using pictures data acquired during the survey. The monument, with a large squared volume placed on a platform, has been entirely photographed in order to give back the conformation of the stone elements and the actual status of those.

Pasargadae, the capital of Cyrus the Great (559–530 BC) and also his last resting place, was a city in ancient Persia (modern-day Iran), located near the city of Shiraz (in Pasargad County) and is today an archaeological site and one of Iran's UNESCO World Heritage Sites. The 160-ha archaeological site of Pasargadae presents some of the earliest manifestations of Persian art and architecture. It includes, among other monuments, the compact limestone tomb on the Morgab plain that once held Cyrus the Great's gilded sarcophagus; Tall-e Takht ("Solomon's Throne"), a great fortified platform built on a hill and later incorporated into a sprawling citadel with substantial mud-brick defences; and the royal ensemble, which

consists of several palaces originally located within a garden layout (the so-called "Four Gardens"). Pasargadae became a prototype for the Persian Garden concept of four quadrants formally divided by waterways or pathways, its architecture characterised by refined details and slender verticality. The diffusion of the image of the mythical Persian cities such as Babylon, Nineveh or Pasargadae, has encouraged over the centuries the taste for the spread of urban green and descriptions of the large overhanging roof gardens civic space, which reproduce the ideas of oasis and utopia prosperity linked to the myth of the city, transcending in an exotic taste will inevitably influence the history of urban green western.





In the description of Xenophon, *Paradeisos* word is mentioned about the gardens of Cyrus, which are full of every good and beautiful thing that the earth has to offer.

In the Persian civilization was expected to use tall trees in the parks and they also planted around the graves, creating gardens and groves to the delight of the souls of the dead. The Persian gardens evoke the natural perfection of the world and that's why they used to call their gardens with the word that is at the origin of our paradise, a term now used to describe the most beautiful and most happy that it exists.

Fortunately Pasagardae showed the remains of the large park surrounding the palace of Cyrus, so it is now possible to reconstruct how they organized the Persians "havens": the royal residence, huge fenced, was made up of luxury pavilions scattered around the garden. It was well squared in the flower beds that were to stretch rows of trees, beautiful and fragrant, described nell'aneddoto of Cyrus. Around the rows ran a network of canals for irrigation covered with decorative white marble, a long chain broken at regular intervals by squared wells, fifty centimeters deep. Alla around there was a rich nature, with large fruitful thanks to the water immersed in an atmosphere where everything was arranged according to the principles of the universal order, a true paradise.

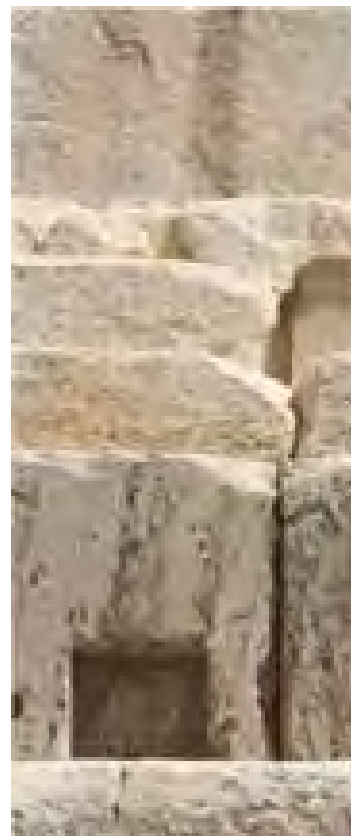
In addition to photography, as support for the design of the models, photogrammetry applied to the study of three-dimensional space has led to the development of software that can export a set of photo sequence in an accurate point clouds arranged in a system of 3D coordinates. If the benefit to reach the point cloud lies in the simplicity instrumental used, the quality control of the process of acquisition and elaboration of the model depends on the automatic reading of the contrasts reported on the support continuous raster of the image that must be transformed into a system of discrete points in space. The open source software for free use allow you to conduct a generic photographic campaign, without the constraints of station, from which, through a fully automated process, develop three-dimensional point cloud of the photographed object. The photographs arranged in the correct sequence are transformed in files opened in management software such as Rapidform or Geomagic.



View a portion of the 3D model with and without texture. From the pattern in gray is it possible to see the characteristic of the surface discontinuities of the material obtained by this survey system. The texture gives to the model the aspects relating to the color and condition of the surface.

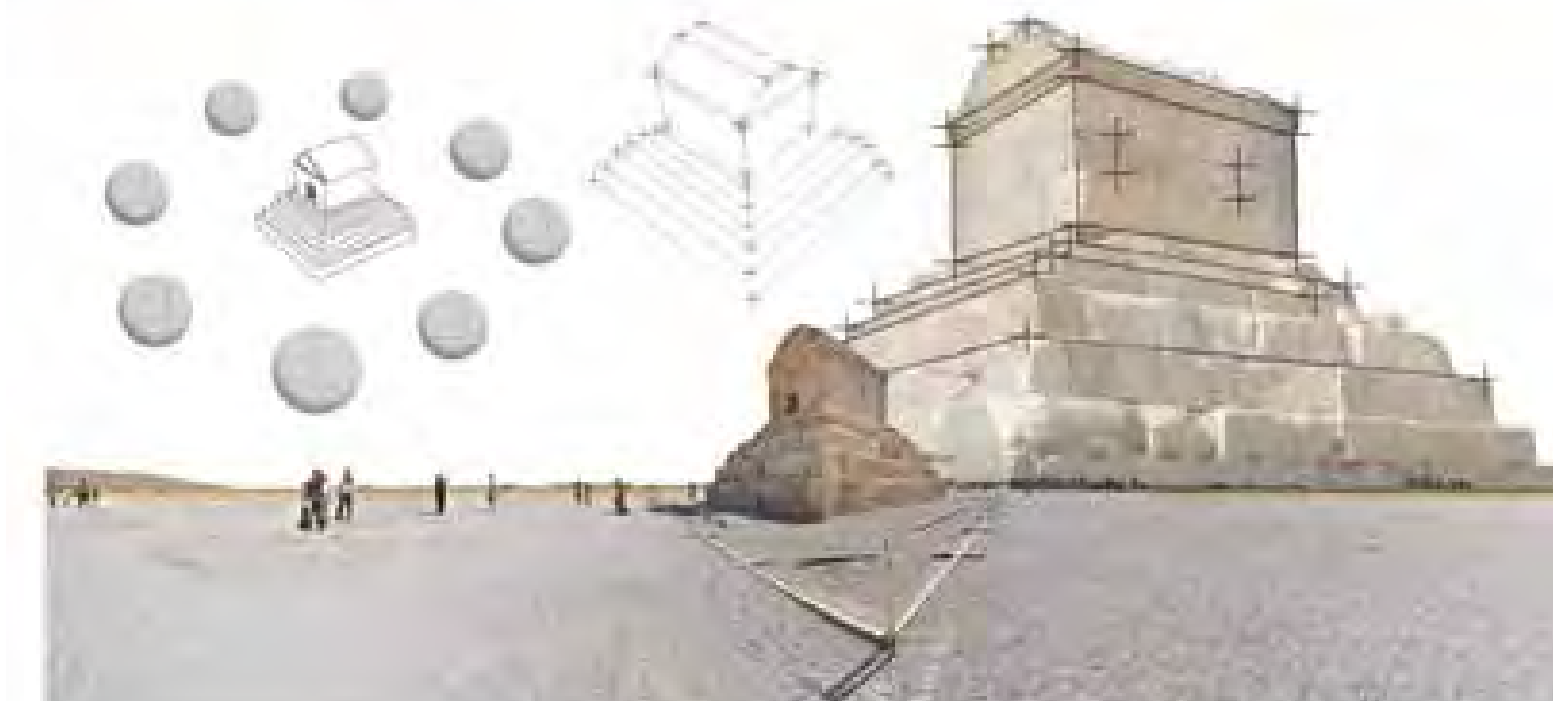


Details of the stairs leading to the tomb. Comparison between the photograph (on the left) and views of the same portion of the model: the polygonal mesh (bottom), the model with texture (next right) and the polygonal mesh merge on the photograph (right).





Elaboration of two-dimensional faces of the Tomb of Cyrus the Great. The model, suitably scaled on three points of the basement measured on site, has allowed to realize a photographic three-dimensional elaborate highly reliable and responsive to reality.



The test of reliability was performed by integrating the *shape from motion* survey methodology with spherical panoramas. These, surrounding the monumental building, allow to find homologous points on the object for each set of three spheres, and locate them in the tri-dimensional space using an orientation and restitution software (Shpera software, Thanks to Prof. Gabriele Fangi, University of Ancona). By overlaying the two products has been checked the reliability between the *shape from motion* model and the spherical model.



The photo modeling allows you to capture data quickly and is a useful tool to generate important architectural drawings and models to explain the morphometric conditions of the system analyzed. Digital archives on cultural heritage are increasingly being used through the integration of 3D models and dynamic drawings, able to promote fruition in the virtual space.

Virtual reality is a tool that allows you to boost the development on heritage: virtual museums, and augmented reality are the basis for the inclusion of the objects considered heritage in interactive databases.



Survey methodology for all the graves. First sequence close to the tombs and the second sequence from the upper level to a overall picture.

The *structure from motion* methodology experimented also for the tombs of the Persian Kings Naqsh-e Rostam. The camera acquisition was carried out from the ground for each tombs.





Survey and documentation of Masada cultural heritage



- SCIENTIFIC BOARD OF THE PROJECT
- TECHNICAL COORDINATOR OF THE PROJECT
- PARTNERSHIP/INVOLVED INSTITUTION
- WHERE AND WHEN
- AIM OF THE PROJECT

STEFANO BERTOCCHI, SANDRO PARRINELLO, REBEKA VITAL

SARA BUA

UNIVERSITY OF FLORENCE; UNIVERSITY OF PAVIA; SHENKAR COLLEGE OF DESIGN AND ENGINEERING ISRAEL; ISRAEL NATURE AND PARKS AUTHORITY; ITALIAN EMBASSY IN TEL AVIV; CYARK 500; PARTNERSHIP FOR TECHNOLOGICAL SUPPORT: AUTODESK; LEICA GEOSYSTEMS; MABAT 3D TECHNOLOGIES LTD.

MASADA NATIONAL PARK, DEAD SEA, ISRAEL, 2012 - IN PROGRESS

The general aim of the project is to create a comprehensive digital documentation of the archaeological site of Masada. The data acquisition has been done through laser scanning and photogrammetry. The point cloud, obtained by scanning the site, was acquired as raw data and was part of the documentation database. Further, the team has processed the point cloud in order to extract data needed to make 2D as-built drawings (plans, sections and elevations), 3D renderings and 2D and 3D details of the elements of interest located in the building.

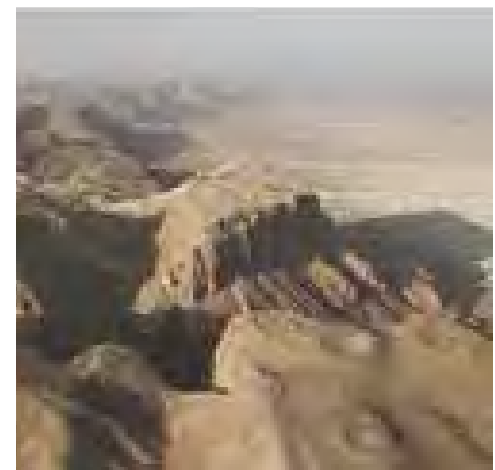
The site of Masada, discovered in 1828 by a traveller on the rugged mountains that rise East of the Dead Sea in the south-eastern Judea, is in current-day part of the Israeli territory at about one hundred kilometres south-east from Jerusalem.

The site had been studied in 1933 by the famous expert Schulte, but only during the excavation activities carried out from 1963 to 1965, the great fortress was identified by the expedition led by the archaeologist Yigael Yadin.

Since 1966, Masada and its territory has become a protected area by the Ministry of Antiquities and starting

from 1998 it was protected as National Parks, Nature Reserves, National Sites and Memorial Sites. It became an UNESCO protected site in 2000 and today it is a wide archaeological park open to tourists, one of the most important in Israel, provided with a Visitors Centre and a funicular railway for a fast connection to the main site area, the fortress, which is located on the wide tableland on the top of the mountain.

There is evidence in the form of archaeological finds in a cave that there was human settlement there in the Chalcolithic period (4th millennium BC) and then in the Early Iron Age (10th -7th century BC).



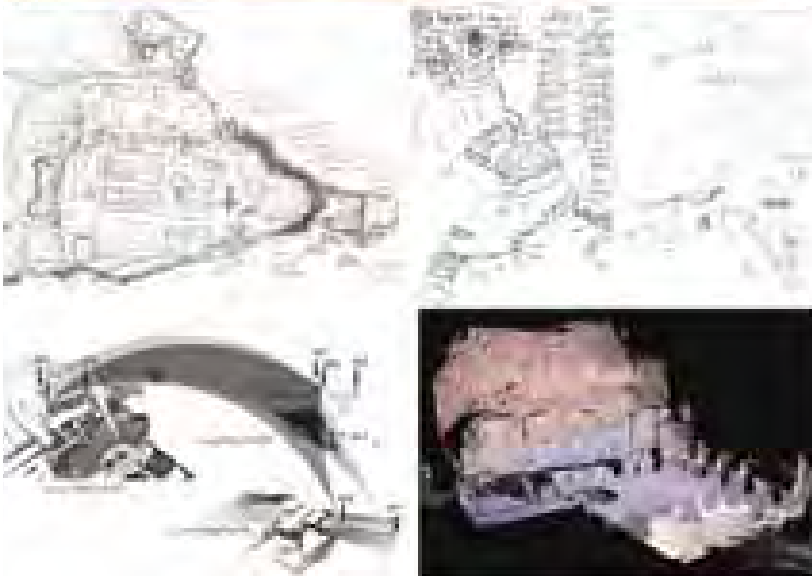
A big artificial underground cistern, together with numerous others basins for water conservation, both on the top of the site and located on the steep slopes of the mountain, demonstrate the long-time human presence in the area. As many historian stated, among them in particular Titus Flavius Josephus, the location had been used as a fortification from the second century BC, due to a rocky isolated mountain with only two access roads. On top of the hill, at a height of about four hundred meters above the Dead Sea depression, there is a flatland of an area of about ten hectares. This summit plateau is fenced in by a walled curtain that extends for about 1,300 meters, and it is made of a double wall, with an outer curtain and reinforcement towers and with an interior wall, connected by transverse walls that form a series of communicating compartments (called casemate system), once used as warehouses, arsenals as

well as residences. Among these spaces there is also a synagogue (considered one of the most ancient of Palestine), and some buildings used as columbaria.

Inside the fortified wall, in the northern area, there is an well-structured building complex: the storehouses, made up of two series of buildings with long rooms (from 20 to 27 metres) and inner road network, the wide residences with inner courtyards, including the so-called Herod's Palace dating back to the first century BC. It is an amazing monumental complex located on three terraces of the rocky summit over the desert and with the beautiful panorama of the Dead Sea.

Within the complex there is also a big watering place (the numerous room have been restored) opened on a courtyard with swimming pool and cisterns.

Another palace complex with various residences is situated in the south-western area of the fortified site and



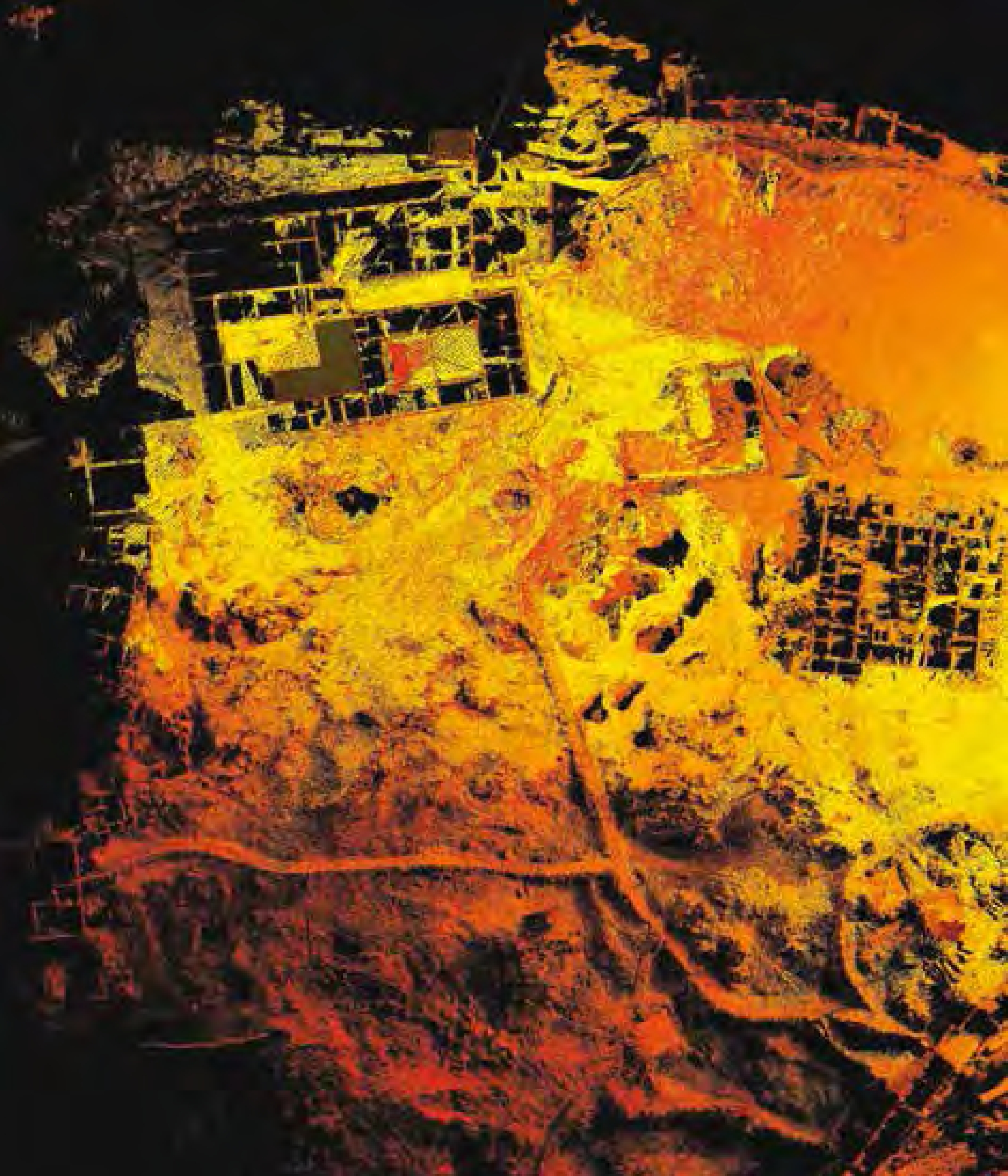
Laser scanner survey: position of the scan stations

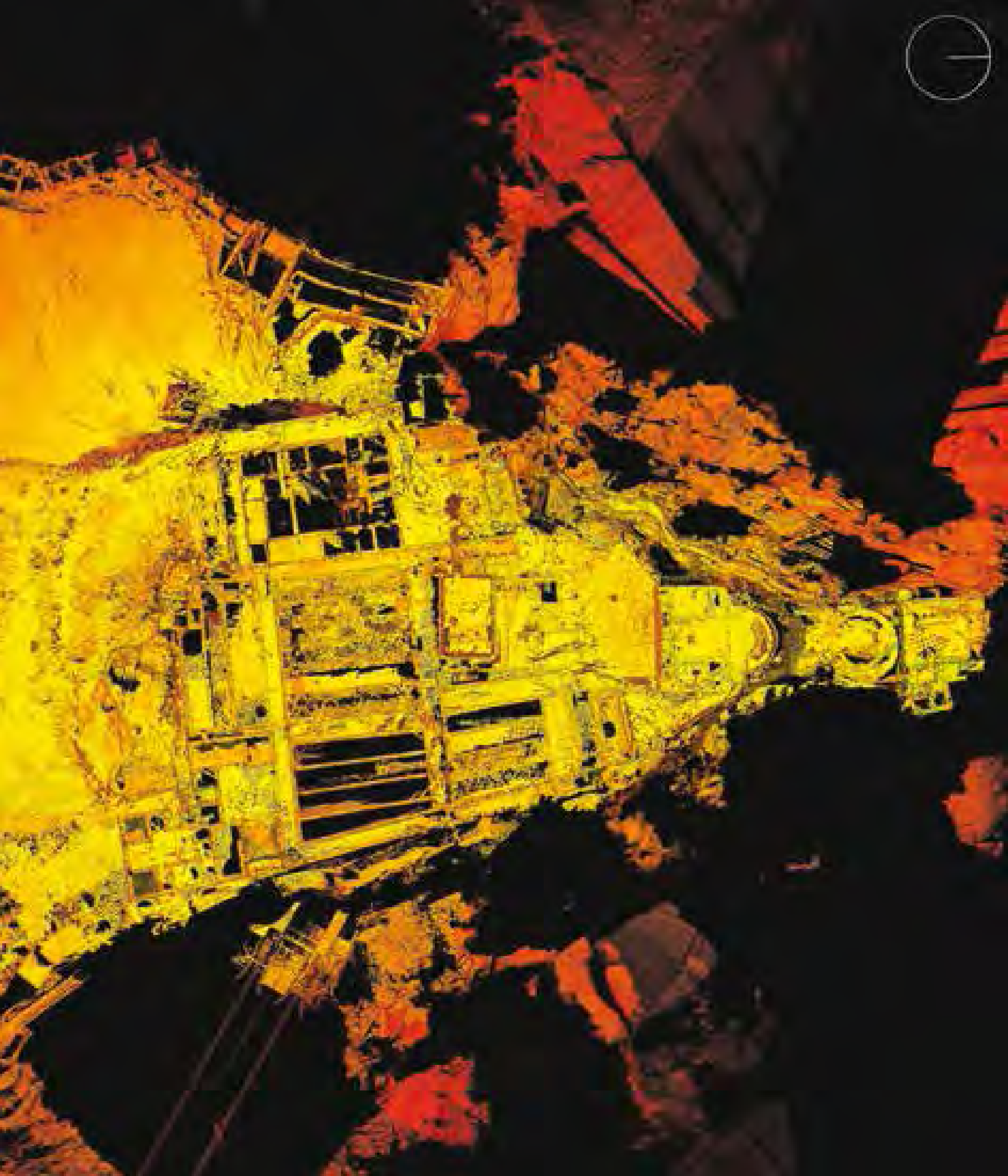
it consist of various rooms around courtyards with unusual long entrance walls. In the central part of the area there are the remains of a building from the Byzantine period, with a central plan, and so the settlement in the site is supposed to exist at least up to that period. Well-preserved also the ruins of the great structures for the siege of Masada, built by the Romans between 72 and 73 AC, consisting of a wall surrounding the hill, reinforced by the presence of eight military camps, fortified with the traditional quadrilateral plan structure. Among the siege structures, the most impressive remain is the artificial ramp, made of earth and protected with wooden structures (some traces still existing), used as sloping plane to reach the walls on the hilltop with an huge siege tower celebrated in the writings by Josephus.

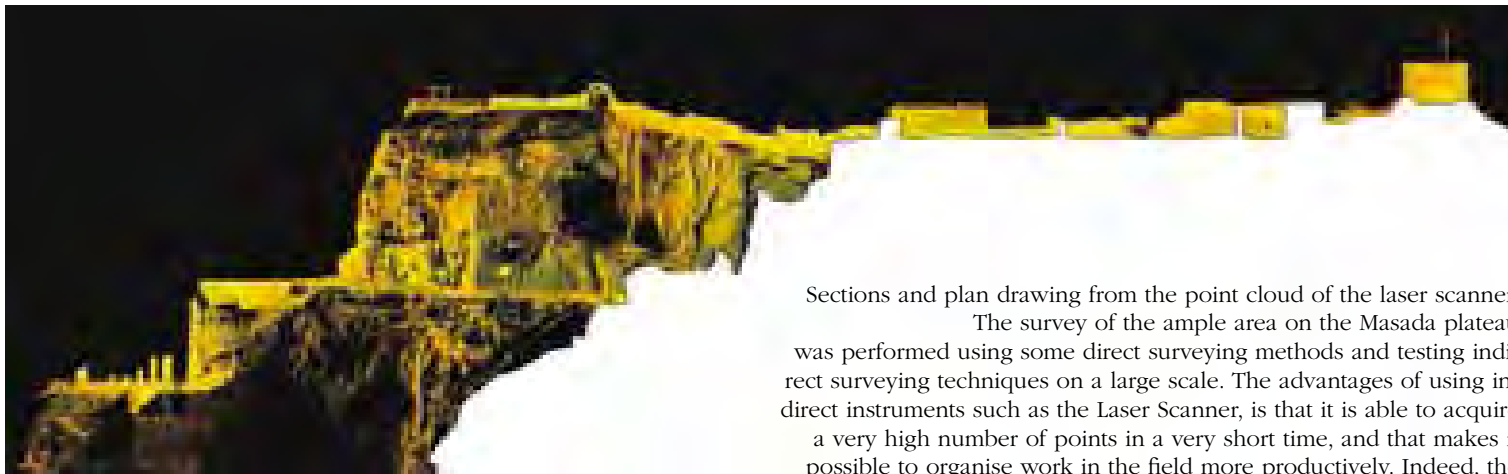


Photographic survey: on the top *shape from motion* methodology for the photographic acquisition. Above the panoramic view of the Masada plateau. The sequence of the pictures can generate a 360° spherical image with the observer in the middle of it. Below the movement around the object to create the right sequence of pictures that can be able to realize a 3D texture model.









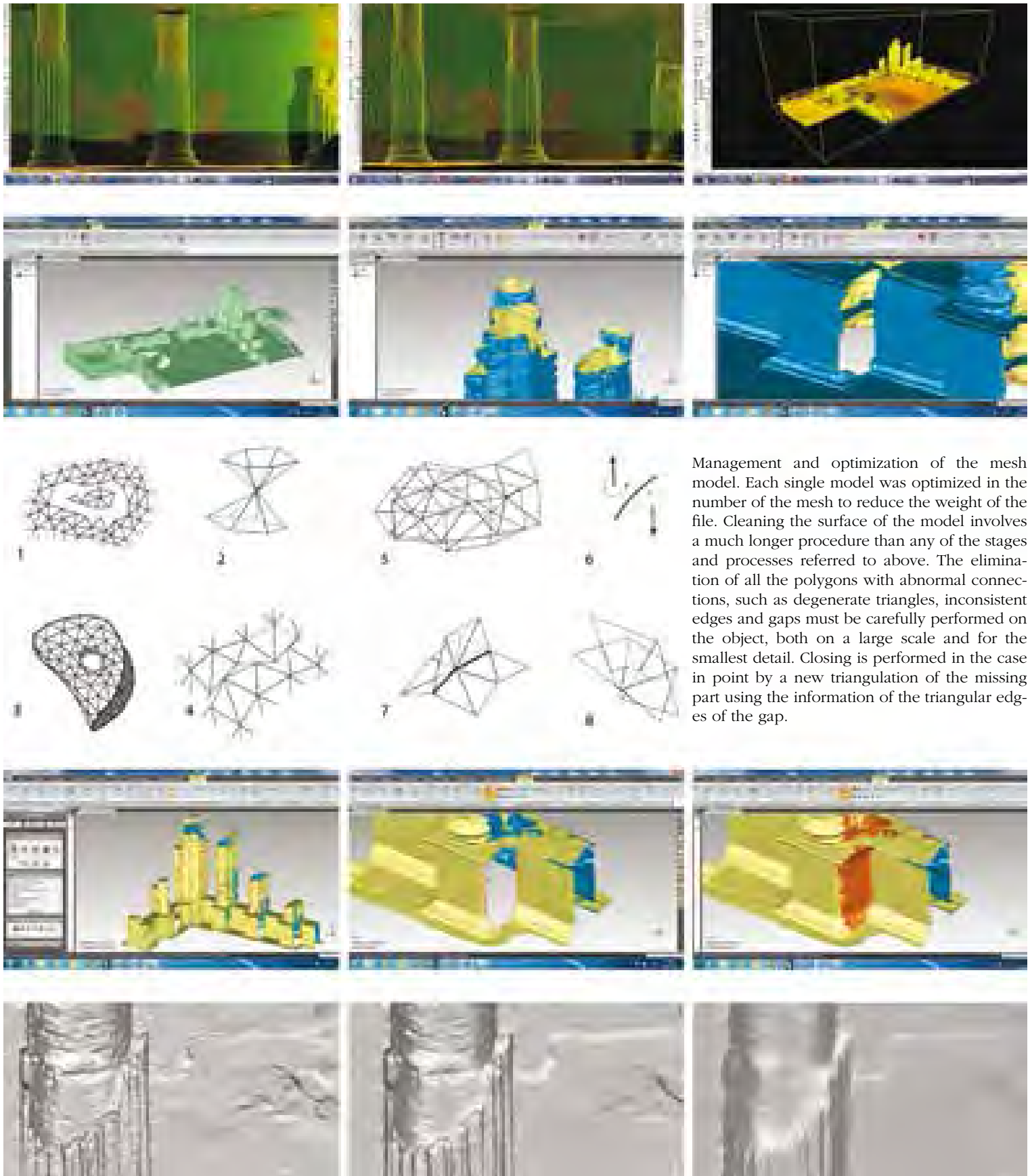
Sections and plan drawing from the point cloud of the laser scanner.

The survey of the ample area on the Masada plateau was performed using some direct surveying methods and testing indirect surveying techniques on a large scale. The advantages of using indirect instruments such as the Laser Scanner, is that it is able to acquire a very high number of points in a very short time, and that makes it possible to organise work in the field more productively. Indeed, the visible surfaces of a given context or architectural object, even a highly complex one, can be fully surveyed using relatively rapid operations that enable one to postpone the longer phase of processing the data acquired to a later stage of the campaign.



Textured Sections of the three levels of Masada plateau. This section was made with the integration of two indirect methodology survey: laser scanner and *shape from motion* for the chromatic aspect.





Management and optimization of the mesh model. Each single model was optimized in the number of the mesh to reduce the weight of the file. Cleaning the surface of the model involves a much longer procedure than any of the stages and processes referred to above. The elimination of all the polygons with abnormal connections, such as degenerate triangles, inconsistent edges and gaps must be carefully performed on the object, both on a large scale and for the smallest detail. Closing is performed in the case in point by a new triangulation of the missing part using the information of the triangular edges of the gap.



The approach used in the first reconstruction was to develop the general figure of the point cloud, create a polygonal surface with a very high density of vertices to then characterise it with all the information related to the colours and state of preservation from the photo.





Models combined into a single project to understand the metric reliability metric on a large scale, in comparison with the point cloud system.



Optimization of mesh: the integration process of the gaps and the reconstruction of the missing portions of the photogrammetric model. The process has been carried out on individual three-dimensional models, subsequently combined.



The management of the 3D model includes a procedure for integrating the products from the two data acquisition systems. The problems of these models are mainly the size of the output file of the tools which, before being managed, need to be substantially reduced in regard to the number of points or surfaces. The mesh model generated by the cloud is then reduced into the number of polygons, so as to make the management of the software rendering or real-time visualisation easier.

The quality of the model is however guaranteed by the excellent resolution of the texture component generated by the photographic sequences around the axis of the object. The texture of the individual photographic models required for mapping the general 3D model of the cloud, is exported in jpg format previously transformed into a surface area of polygons.

The experiments on the subject showed the level of detail achieved by models with the same texture, in which the polygonal mesh was more or less reduced, and therefore the level of morphological detail proves more approximated in geometry but not in the graphic rendering.

The results obtained and processed to date for some of the buildings in this area, made it possible to test the effective reliability in the alignment of the individual models, the relative and absolute rototranslations on the basis of the reference laser scan.

The advantage of obtaining three-dimensional models from the photos immediately is that of being able to test the perfect match between the polygonal mesh and the reference texture that it is generated on.

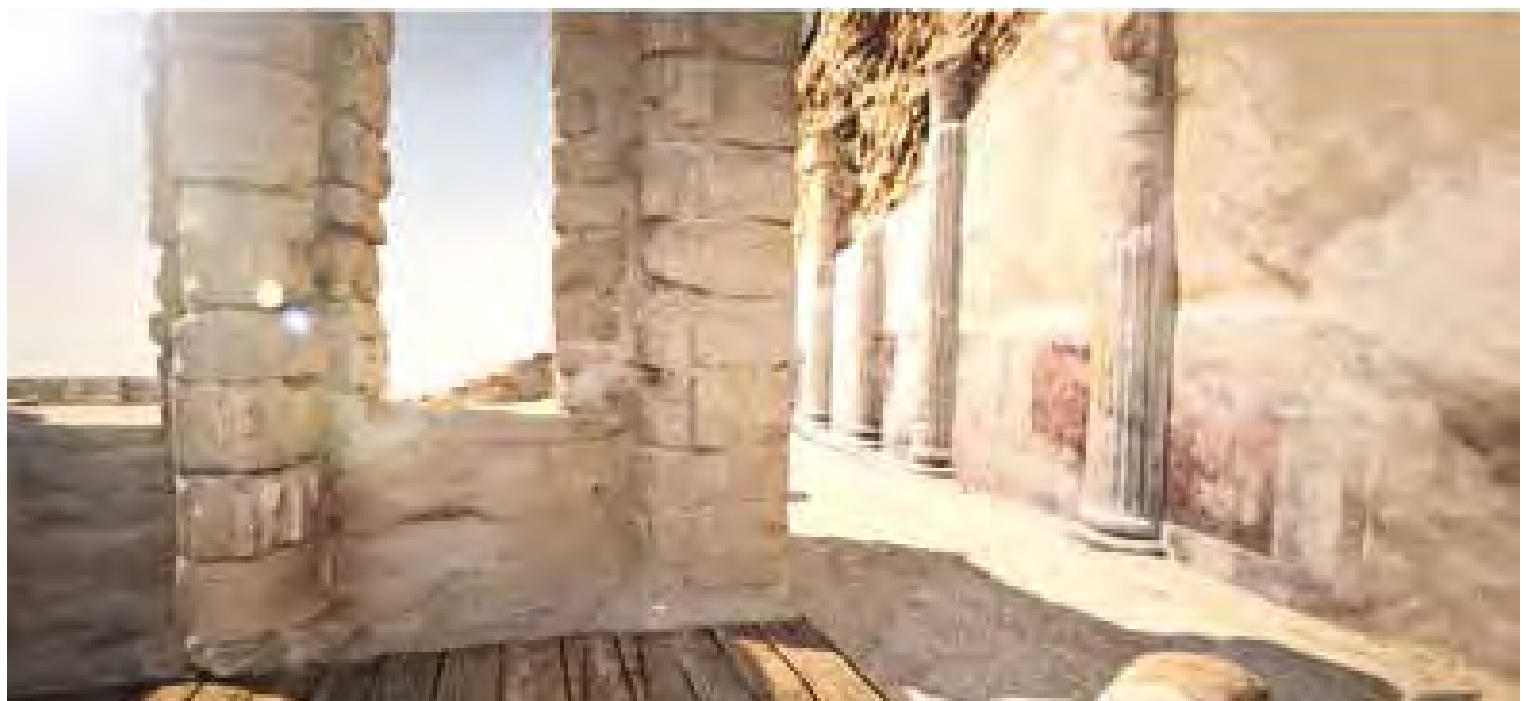
However, the processing and management of the mesh of polygons is not always easy and immediate. A number of problems arise with the mesh generated by photomodeling related to gaps and discrepancies in the polygonal mesh.

The model thus generated is a good basis for a number of considerations, combining the geometric reliability obtained by laser instruments, useful when considering the morphological-geometric nature, with a material quality obtained from instrumentation based on photographic images, needed for considerations on the state of conservation of the building.



Completed the three-dimensional model and imported into programs of real-time navigation.







An experience of scientific collaboration for the documentation of Hadrian's Villa archaeological site

■ SCIENTIFIC BOARD OF THE PROJECT

STEFANO BERTOCCHI, LUCA CIPRIANI, SANDRO PARRINELLO

■ TECHNICAL COORDINATOR OF THE PROJECT

FILIPPO FANTINI, SERGIO DI TONDO

■ PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE; UNIVERSITY OF PAVIA; UNIVERSITY OF BOLOGNA; SOPRINTENDENZA PER I BENI ARCHEOLOGICI DEL LAZIO - AREA ARCHEOLOGICA DI VILLA ADRIANA; PARTNERSHIP FOR TECHNOLOGICAL SUPPORT: MICROGEO SRL.

■ WHERE AND WHEN

TIVOLI (ROME), ITALY, 2012 - IN PROGRESS

■ AIM OF THE PROJECT

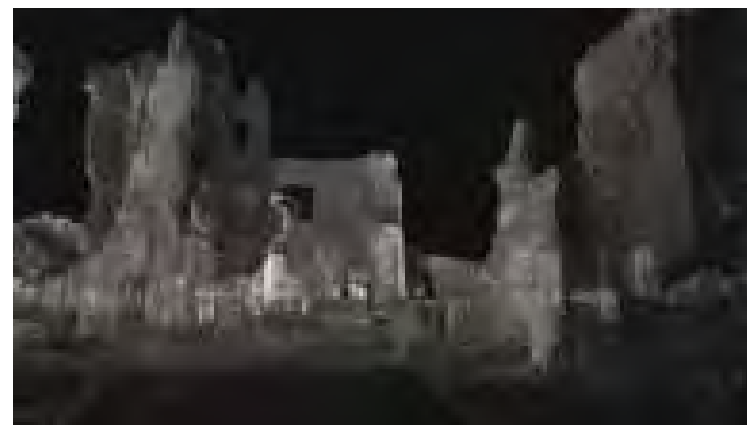
The survey campaign carried out at Hadrian's Villa, near Tivoli, focuses on three areas of the great Imperial mansion: the so-called "Area di Palazzo", the Courtyard of the Libraries and the Maritime Theatre. In addition, a series of elements belonging to architectural decoration have been digitally captured. Topographic and 3D laser scanner devices, together with photo-modelling applications based on Structure From Motion, provided to the research team a uniform framework for the documentation of the Villa at different levels of detail.

INTRODUCTION

The villa was built by the Emperor Hadrian (117 and 138 AD) in the vicinity of Tivoli, a town of ancient origins, located east of Rome along the Aniene River nearby the large waterfall. This charming area has been enjoyed since ancient times for its favourable climate conditions and the fascinating environment. The abundance of water was another relevant feature of the site that, in the course of time, made easier the construction of the great imperial mansion. The Villa was erected on the top of a series of *plateaux*, located between two tributaries of the Aniene River, at the foot of

the so-called Colli di Santo Stefano. It is the largest and most famous of imperial villas of ancient Rome and stands out for its imposing grandeur of the architecture, consisting of a set of monumental buildings, a dense network of underground passages, pools, thermal baths, libraries and building for spectacles. The scale of Hadrian's dwelling makes it a city rather than a villa, in fact it is spread all over an area of about 120 hectares that hosts several sets of buildings with different and distinctive features and orientations: representative and protocol buildings (Imperial Palace), thermal areas (Small and Large Baths, Baths with Heliocaminus),





summer and winter apartments, but also pavilions aimed at social entertainment like *triclinia*, theatres, one arena for gladiatorial fights and so on. After Hadrian's death, the Villa remained a part of the assets of the Imperial House. In the following centuries, and especially during the Middle Ages, the site suffered a gradual decline and was looted of its marbles, used in many buildings (in Tivoli and Rome) as well as in churches and museums. The Villa was re-discovered in the Renaissance and it was a source of inspiration for architects and artists coming from Italy and from other countries, who admired the general composition of the mansion, the original shape of its vaulted spaces and the refined stile of its architectural decoration. An intense excavation activity started, this took to discover valuable marble sculptures and architectural elements decorated with refined ornaments. The acquisition in the collection of the noble families of the time has determined the dispersion of the larger part of the decorative apparatus of the Villa. Now almost every one of those elements can be found in the most important Italian

and European museums and collection. Systematic scientific researches started with the Italian Unification, with the acquisition of the bigger part of the actual archaeological area of Villa Adriana happened in 1870. After the exceptional finds, during 1950s, of the Canopo and of the famous statues that decorated the border of it, the whole archaeological area underwent to important recovery works: many restoration works were carried out, the water in the pool was restored, the columns and the trabeations were repositioned in many buildings of the Villa. After the Unification of Italy, the Italian State obtained the ownship of the site. The Hadrian's Villa is currently under the protection of Soprintendenza per i Beni Archeologici del Lazio (MiBACT), in charge of its safeguard and fostering cultural activities such as exhibitions, concerts and performances with the purpose of promoting its wider knowledge and appreciation. From 1999 the site was declared a World Heritage Site, is included in the World Heritage List.

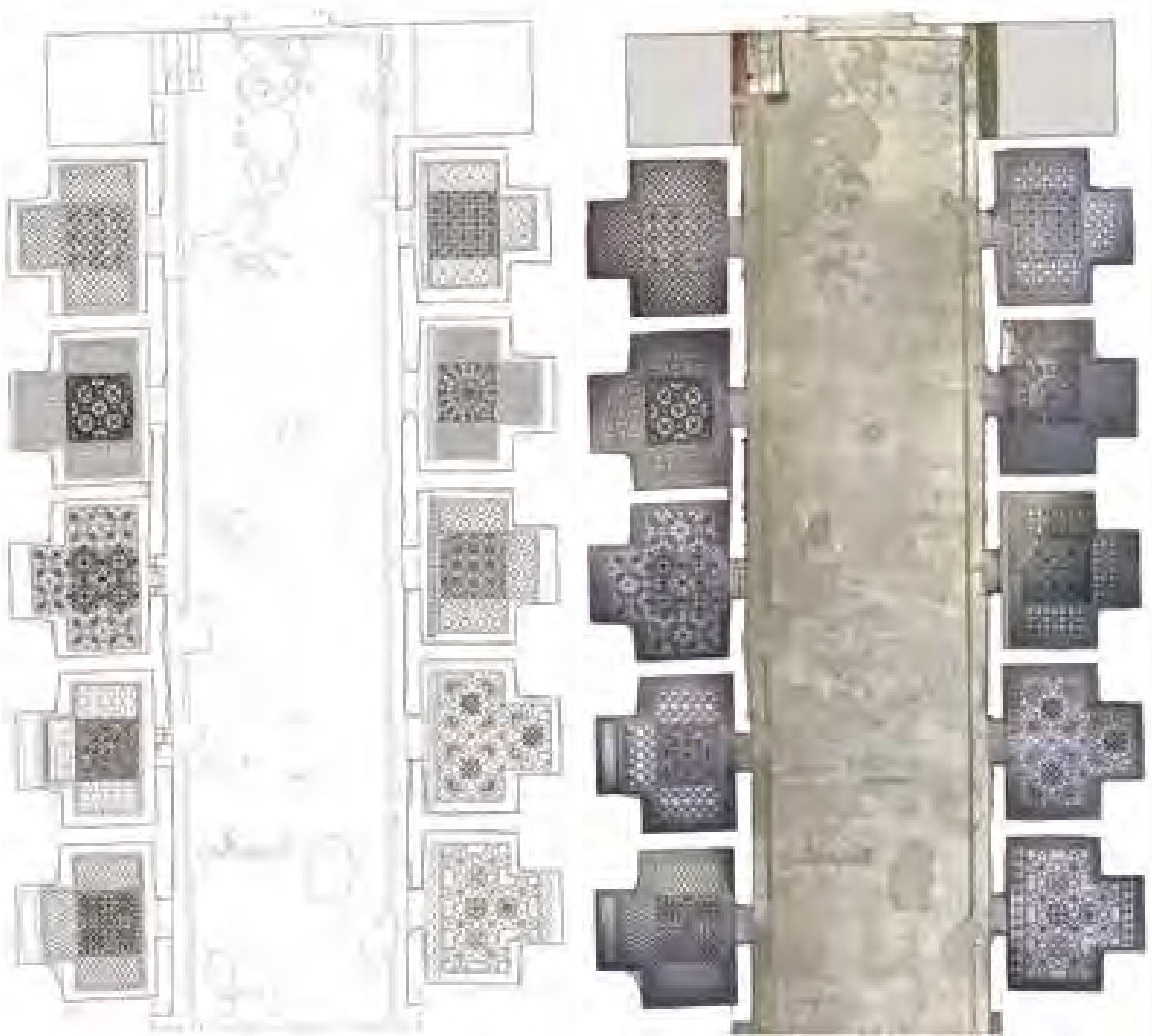
(B.A.)



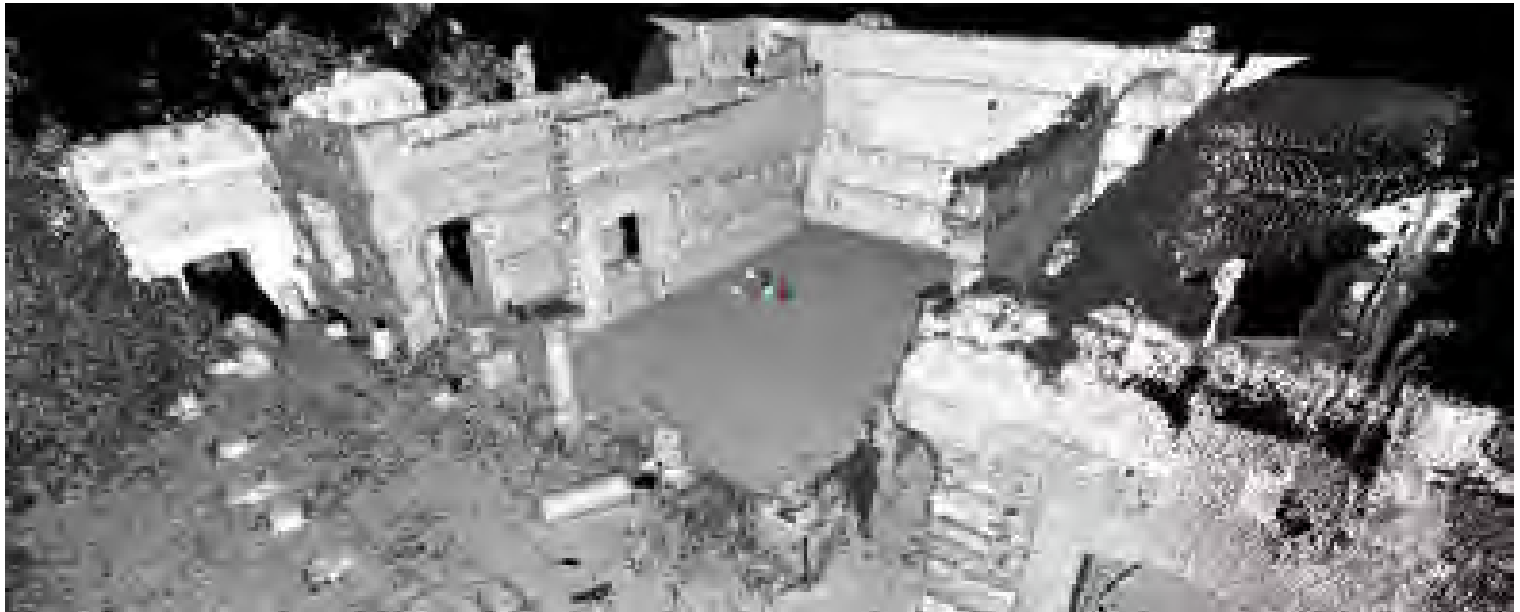
3D MODELS FOR ARCHAEOLOGY

3D models have gained great popularity for their capability to open a realistic view on the former, ancient image of archaeological sites. Virtual reconstructions, virtual anastilosis, 3D animations, still images of the original shapes of towns and their main monuments became widespread inside museums, interpretation centres and exhibitions. Those kind of 3D models are used for diffusion, dissemination practices and are in general built by means of common computer graphic applications,

characterized by effective polygonal modelling tools, state of the art mapping/texturing, and robust lighting and material/surface simulation algorithms (radiosity, global illumination, unbiased render engines, etc.). The aim of these models is not so far from being a geometrically simplified representation of the reconstructive hypothesis (in other words, low polygonal models), where the role of textures, reproducing the aspects of masonry walls, frescos, mosaics, is fundamental to let visitors and tourists understand the formal appearance of ancient



Hospitalia area: 2D drawing in CAD and orthoimage of the plan.





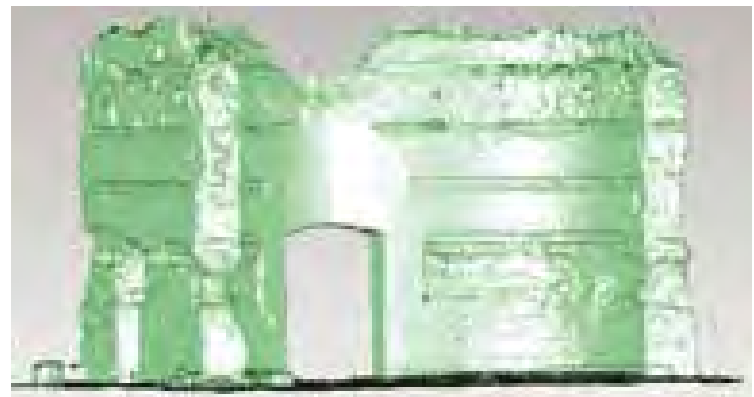
Textured sections of Imperial Palace area. The path was obtained by *structure from motion* methodology, integrated to a laser scanner survey base.

On the right side: Products of two-dimensional and three-dimensional area of the library. The plants and the main sections presented describe the material aspect of the different environmental sections, processed through the orthoimage of photographic images of each element, in plan and elevation.



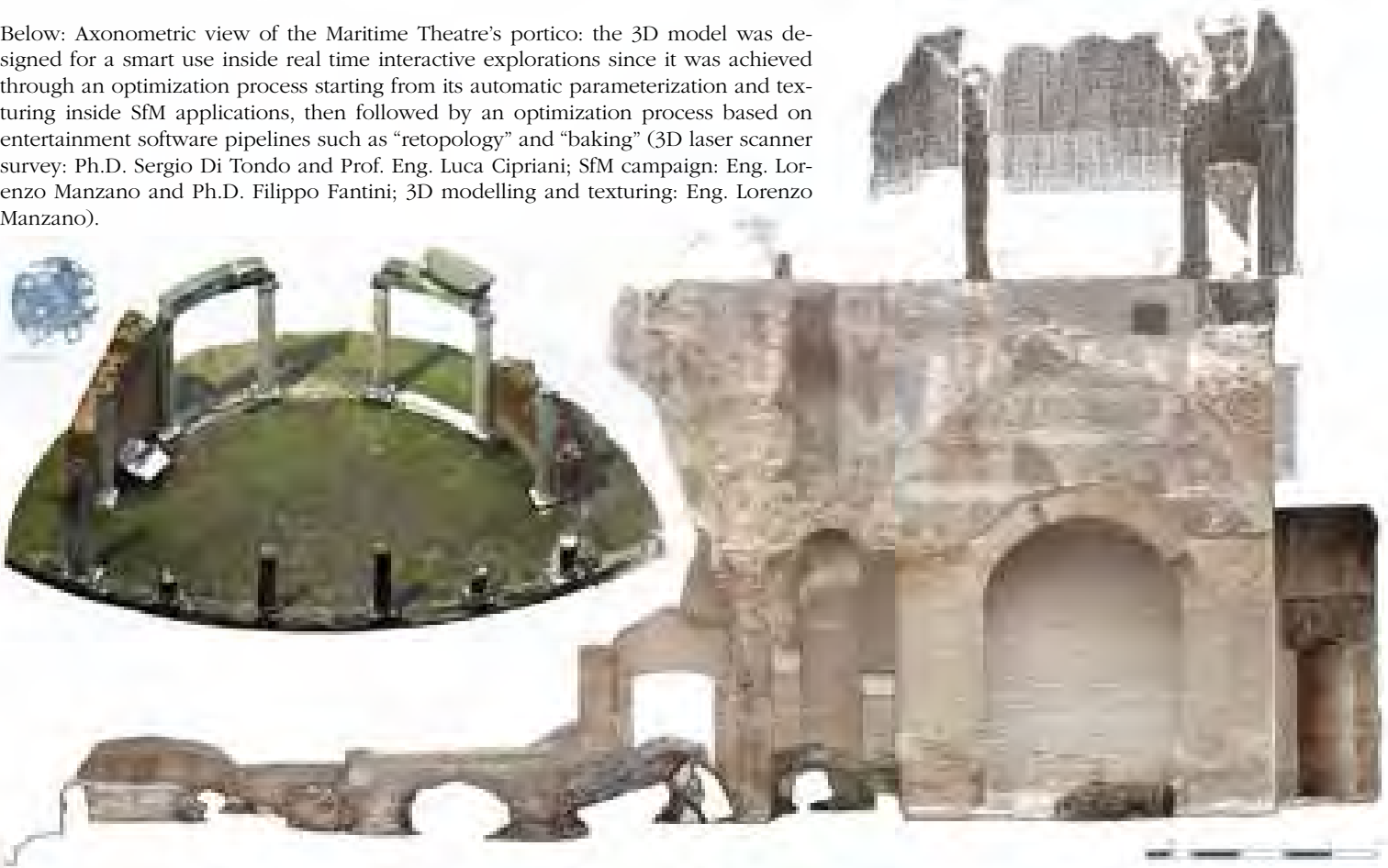
monuments or urban realities. 3D assets and items of this kind are the same of those used inside real-time applications (videogames) or broadcast and cinematographic animations; the methodology used their creation is almost standardized and in general does not deal with the aims of a scientific documentation of the built heritage; at the contrary archaeologists and architects make their drawings, photos, sketches and surveys (made traditionally or with technological devices as laser scanners or Structure From Motion applications, SFM) with a different focus, where quantitative aspects, and not just visual appearance are the main purpose.

(F. F.)





Below: Axonometric view of the Maritime Theatre's portico: the 3D model was designed for a smart use inside real time interactive explorations since it was achieved through an optimization process starting from its automatic parameterization and texturing inside SfM applications, then followed by an optimization process based on entertainment software pipelines such as "retopology" and "baking" (3D laser scanner survey: Ph.D. Sergio Di Tondo and Prof. Eng. Luca Cipriani; SfM campaign: Eng. Lorenzo Manzano and Ph.D. Filippo Fantini; 3D modelling and texturing: Eng. Lorenzo Manzano).



PROCESSING THE ACQUIRED DATA IN RAPIDFORM

Alignment of the individual scans on the basis of the known coordinates of each of them.



FIRST OUTPUT

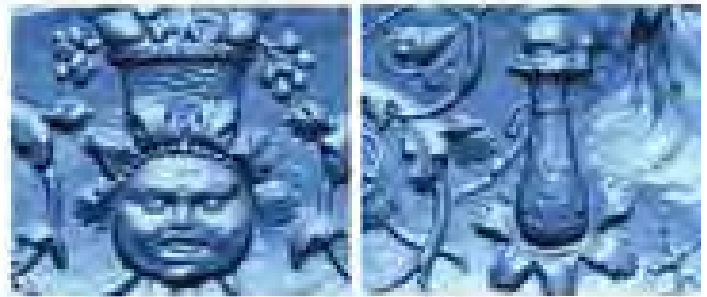


MESH PROCESSING IN RAPIDFORM

the defects of the mesh have been eliminated by *Global Remesh* and *Fill holes* tools.



SECOND OUTPUT



PROCESSING THE ACQUIRED DATA IN PHOTOSCAN

The software allows to *align* the photos automatically. It generate a dense cloud from which obtain a mesh.

After that is possible to generate a texture with *Build Texture* tool.



FIRST OUTPUT

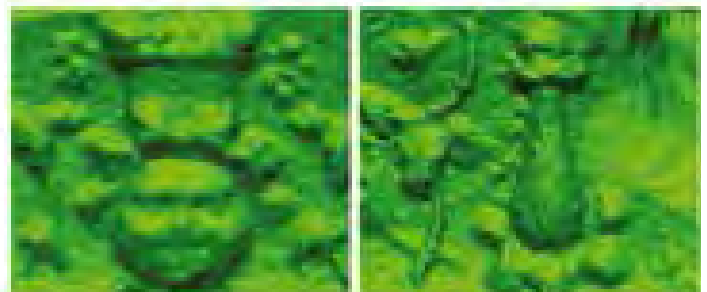


MESH PROCESSING IN RAPIDFORM

The mesh, also after the improvement with Global remesh and fill holes tools, will be less reliable than the mesh made with laser scanner technology.



SECOND OUTPUT



APPLICATION OF THE TEXTURE



SECTION PROCESSING



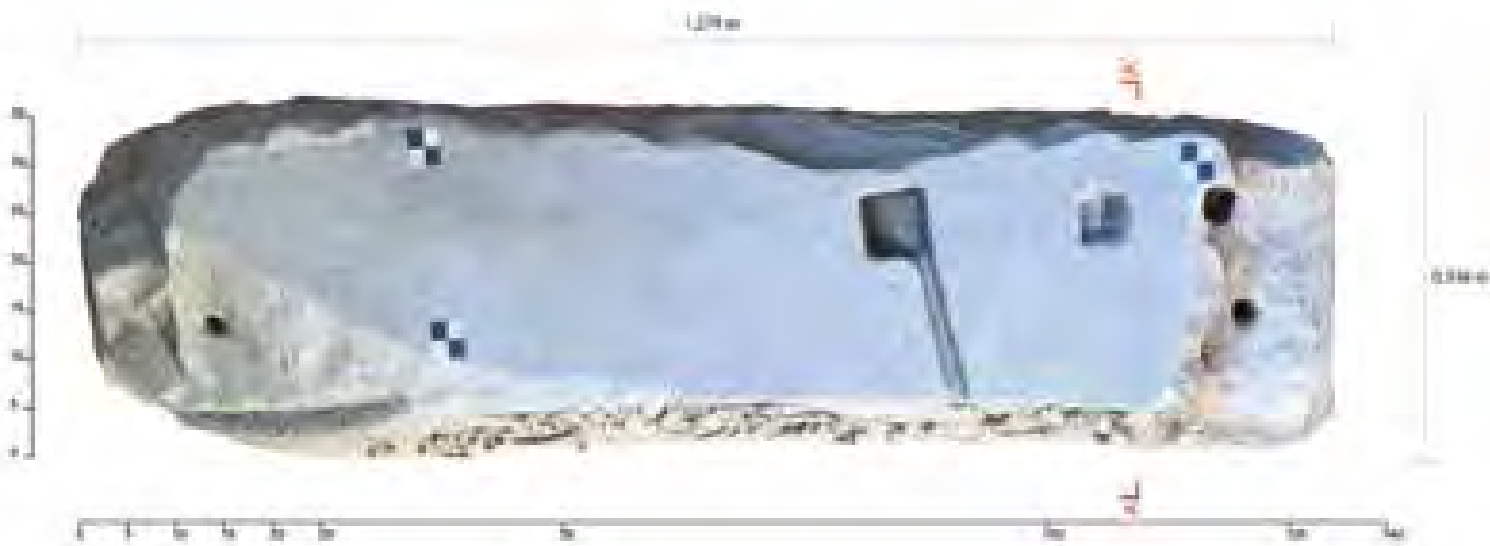
VERTICAL SECTION

ORIZONTAL SECTION

One of the investigation lines carried out by Soprintendenza per i Beni Archeologici del Lazio deals with the documentation of the architectural decoration, for the achievement of a better understanding of the original location of these finds. In this case, a fragment of decorated pillar from the Serapeum area was surveyed using a multiple laser stripe laser scanner device.



FRONTAL VIEW



ZENTAL VIEW



The survey of Villa del Casale, Piazza Armerina, in Sicily

SCIENTIFIC BOARD OF THE PROJECT

GUIDO MELI, LEONARDO CHIECHI

PARTNERSHIP/INVOLVED INSTITUTION

REGIONE SICILIANA – DIPARTIMENTO BENI CULTURALI E IDENTITÀ SICILIANA – SOPRINTENDENZA AI BENI CULTURALI DI ENNA; MUSEO DELLA VILLA ROMANA DEL CASALE A PIAZZA ARMERINA; CONSORZIO OBC; COOPERATIVA ARCHEOLOGIA; DIGITARCA (MEMBER OF THE JOINT LABORATORY LANDSCAPE SURVEY & DESIGN).

WHERE AND WHEN

PIAZZA ARMERINA (EN), SICILY (IT); 2007-2013.

AIM OF THE PROJECT

Improved shell for the purpose of better conservation and visitability the Roman Villa and restoration of decorative systems. survey and architectural drawings of the complex.

INTRODUCTION

The Villa constitutes one of the most popular historic witnesses of the ancient age in the Mediterranean area. In 1997, it became part of the UNESCO World Heritage List. The functional recovery and the restoration work of Villa Romana del Casale started in 2007. It concerns the substitution of the old covers, realized by Franco Minissi during the 60s, restoration of the mosaic surfaces, wall surfaces and stone surfaces. Fundamental to realize the new covers was the verification and the updates of the design data. This verification is based on the laser scanning survey. The drawings of 3D detail related to the manufactures of the wooden and iron structural parts, to be defined with numeric control high-precision machines, are based on the survey. The detail drawings have verified every

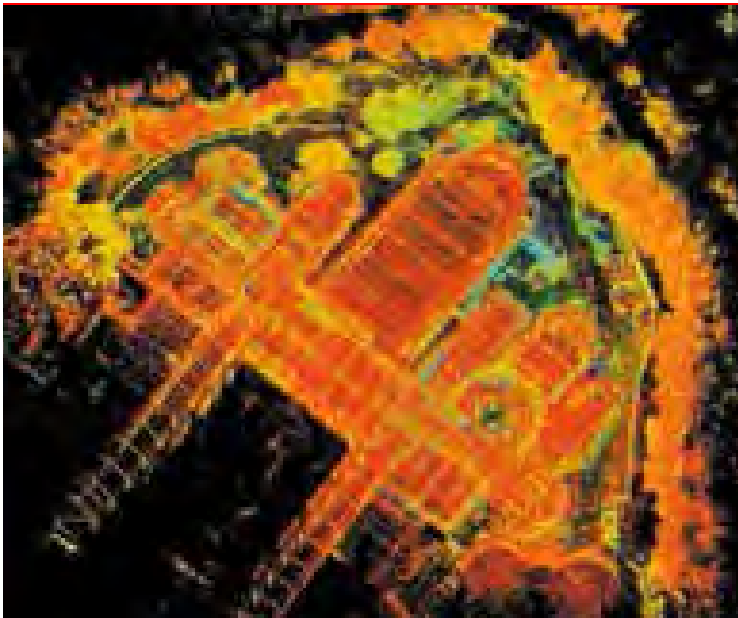
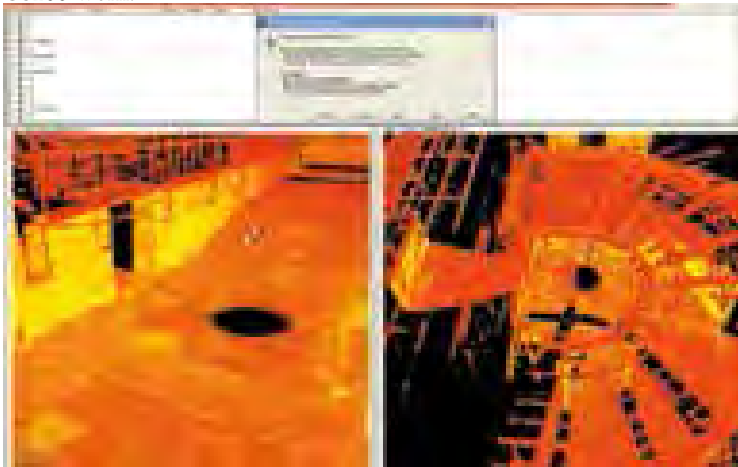
structural connections, wood - wood, iron - iron, iron - wood and the connections with the copper - plate cover. The detail drawings have been important to the workshop drawings. They comprehended also, the footbridges linked between them, the curved parts of the apses and the links between the many parts of the building. The drawings of the detail have been assembled in a unique 3D vision, also for the partial parts, with the possibility to verify the model from both the outside and the inside. It is possible, also, to scale the model up to 1/5 scale and to navigate inside the parts of the building. The realization of 3D drawings allowed to automatically obtain detailed plans, mounting schemes, measurements and it allows the direct transfer of the data to the number - control machines for the production of elements.

(R. B.)





above: In the picture, the laser scanners Callidus CP3200 and Mensi GS200 work.



Above is a screenshot of the registration (alignment) module of the various scans. The right frame displays a different scan than the left; you can also see the error datasheets. Below the image of the point cloud of the entire site.

SURVEY ACTIVITY

The survey of the site of Villa del Casale was carried out using terrestrial laser scanning technology TOF (time of flight) and photographic HDR (high dynamic range) shoots at high resolution. The size and design of the historic site have greatly influenced the choice of the station points of the instrumentation and the execution of the survey. The Villa, of late-Roman period, is located on a sloping hillside and has a development on terraces; the design follows the traditional Roman villa, divided into four distinct groups each physically and functionally oriented along a different axis that converge towards the great square peristyle. Since 1950 years it was brought to light only a portion of the residence, the ruins consist of an area of nearly 4000 square meters of which 3500 covered with mosaics of great value. Following the inspection and because of the morphology of the area, the consistency of the vestiges and the distribution of the environments, the station points of the laser scanner have been chosen to ensure an overlap of the scans such as to realize a single three-dimensional model by limiting the formation of shadows and then gaps in the point cloud.

The survey has been conducted in two distinct phases; for the first, two laser have been used, with different characteristics and that can be integrated with each other, the laser scanner Callidus CP3200, with a range of 80m, ideal for the interior areas, and the laser scanner GS200 MENSİ, with a range of 350m, ideal for large structures; in a second phase, some parts were integrated with the Leica HDS 6000 laser scanner, with a range of 50m, which has resulted in a greater degree of detail and more dense point cloud in certain areas.

A total of 197 scans were done, aligned and joined into a single three-dimensional model during the registration phase through the use of the algorithm of the homologous points between the different stations for some areas. For other, such as the peristyle, spherical targets were also used. The cloud of points obtained in this way has been cleared by automatic filters, from noise generated by the angle of the laser beam and any outside interference.

In addition, the technology used has allowed, through the detection of different degrees of reflectance of the areas affected by the laser beam, to acquire and restore even the subjects represented in the mosaic floors as well as the morphology of the site and mosaic tiles.

The laser scanning has been complemented by an acquisition in high resolution using the camera CANON ES 450D with photographic kit for panoramic shots, calibrated to be matched to the acquisition of the 3D scanner; such in-

strumentation mounted in the station points of the scanner scanner has allowed the realization of the corresponding equirectangular that make up the RGB color of the laser data; every picture taken is a combination of 3 shots at three different exposures, capturing all the details in shadow and light. In the laboratory, the 3 shots were merged into one in order to get the dynamic range HDR, which allowed us to equalize the illumination of the entire site. The model thus obtained was used in post-production for processing two-dimensional and three-dimensional deliverables and for the creation of orthorectified photos of mosaics of the Great Hunt, the Maidens in Bikini and the peristyle. This type of processing is achieved by an orthomosaicking in the plane of the chosen view, where the individual photos were rectified thanks to the simultaneous data capture of photos and metric.

The consistency of the survey data also allowed us to conduct a study of deviation between the planes of the mosaic floors and an ideal perfectly horizontal plane.

The 3D modeling of the site was carried out using two different techniques, the roofs with cad reconstruction and the triangulation of the cloud for the ruins. The triangulation uses special softwares that through interpolation parameters generate a polygonal mesh. The model obtained was then processed in order to achieve the desired resolution; applying filters of automatic cleaning and fill-holes, imperfections were removed and small holes closed, and we had to manually intervene to supplement any lack of data.

The 3D thus obtained was then textured using the technique of inverse perspective that allowed to photogrammetric dress the 3d model with its actual real skin, and the express hypothesis of virtual restoration of the gaps in the mosaic carpet.

(L. C.)



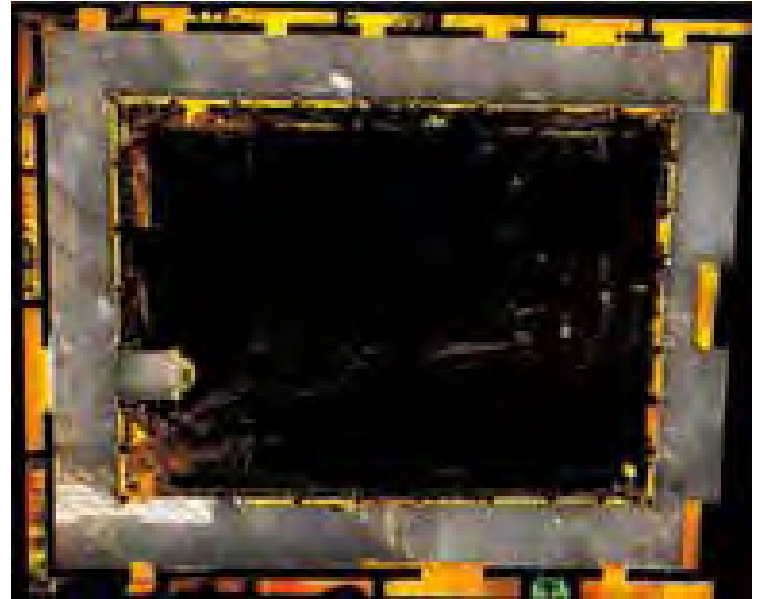
Above: the image of the point cloud, in false color reflectance of the peristyle.



Above: the plan on the left shows the placement of the instrument laser scanner. The station points were determined in order to obtain registration of a single model.

The photo below is the view in a single shot of an equirectangular photo made during the survey.





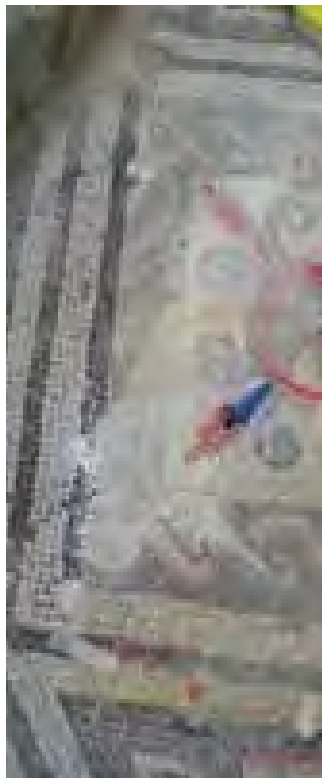
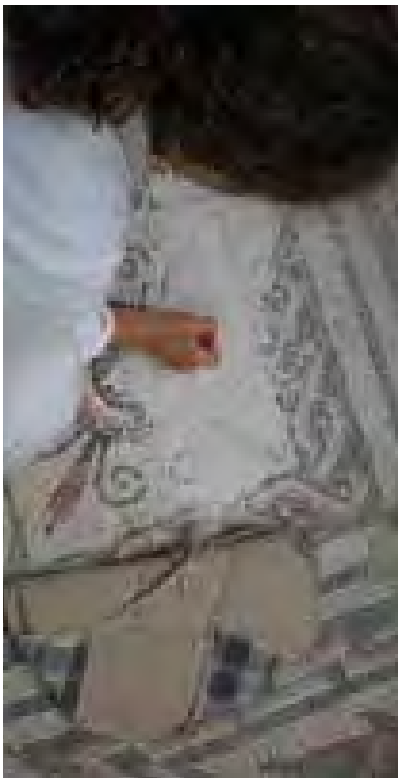
Left, above: the comparison between the orthoimage and the orthophoto of a piece of the mosaic of the Great Hunt shows how the orthorectification techniques allow to obtain a photo metrically reliable, corresponding to the cloud point by point.

Above, the drawing with mosaicking of the orthorectified photo of the mosaic pavement of the square peristyle.

RESTORATION WORKS

The restoration of the decoration of floors and walls has been performed ensuring a general operation of preservation, in order to stop or to strongly delay the deterioration processes. The needed operations for the restoring have been supported by all the necessary laboratory analysis. Every single case (almost 4000 squared meters of mosaics and marbles, painted plasters and stone elements) has been studied in order to apply the correct restoring operations. Professionals have conducted the cleaning and restoration of the mosaics, many restorers alternated during these years of work, developing innovative techniques. Slime, molds, algae, bacteria, fungi and salts have been removed; the cards have been cleaned (many of them have been damaged by the materials used during previous restorations); some small portions of mosaics have been detached in order to intervene on the stained iron of the cement screed; inside the ground have been infiltrated healing products, the barium hydroxide, injected between the cards of the mosaic, removed some salts and renewed its solidity. In addition, here was used, for the first time, a precious reconstructive technique. This technique allowed the reconfiguration of the geometric gaps, giving the chance to recover a big portion of the original mosaics.

(R. B.)





Details of the restoration of the mosaic before and after the intervention.



The image above proposes the study of the deviation of the plane of the mosaic floor of the room Girls in Bikinis. At the side, the orthophoto of the above flooring.

Below, two images showing the three-dimensional model with texture.





Documentation for Restoration of the Nativity Church in Bethlehem



SCIENTIFIC BOARD OF THE PROJECT

GIAMMARCO PIACENTI, SANDRO PARRINELLO

PARTNERSHIP/INVOLVED INSTITUTION

PALESTINIAN PRESIDENTIAL NATIONAL COMMITTEE, PIACENTI SPA, COMMUNITY DEVELOPMENT GROUP UNIVERSITY OF FERRARA, SADLAB STRUCTURAL ANALYSIS & DESIGN LABORATORY, CFR CONSORZIO FERRARA RICERCHE, UNIVERSITY OF ROME "SAPIENZA", GRADUATE PROGRAM IN ARCHITECTURAL HERITAGE AND LANDSCAPE FOR THE STUDY OF MONUMENTS AND HISTORIC PRESERVATION, CNR-IVALSA OF FLORENCE, TREES AND TIMBER INSTITUTE, UNIVERSITY OF SIENA, CNR IVALSA FLORENCE, UNIVERSITY OF NAPLES FEDERICO II, UNIVERSITY LA SAPIENZA, CMW, LEGNODOC, BGREEN, ALMAHER CONSTRUCTION & CO, UNIVERSITY OF FLORENCE, DEPARTMENT OF ARCHITECTURE, UNIVERSITY OF PAVIA, DEPARTMENT OF CIVIL ENGINEERING AND ARCHITECTURE.

WHERE AND WHEN

BETHLEHEM, PALESTINE, 2014

AIM OF THE PROJECT

ARCHITECTURAL SURVEY OF THE COMPLEX OF THE BASILICA OF THE NATIVITY IN SUPPORT OF THE RESTORATION AND CONSOLIDATION WORK OF THE CHURCH.

"Ubi natus est Dominus Iesus Christus, ibi basilica facta est iusso Constantini." [B. Bagatti, *Gli Antichi Edifici Sacri di Betlemme*, Franciscan Printing press Jerusalem (1983)]. This is the first evidence of the Nativity Church located in Bethlehem, Palestine. The original structure was destroyed and rebuilt during the Justinian period, and it was modified and restored many times in the history. The roof of the Nativity Church has come to us in the worst conditions: water infiltration, microbiological attack to the wooden structures, insects. An Italian restoration company Piacenti spa, from Prato, has begun the works on September 2013, on the roof sys-

tem and windows, after winning the tender announced from the Palestinian National Authority, and on August 2014 on the external stones, narthex, plasters and wall mosaics. The first working phases have been the whole project study, the architectural survey, the safety measures in order to work trying to maintain the religious celebrations of the Church.

The technicians and the restorers carried out the first general dilapidation, archeological, diagnostic survey of all the artistic surfaces of the Church, this was due to the imminent scaffolding system assembly to arrive in safety on the roof level. After protection of columns,





architraves, floor, wall and floor mosaics, the skilled workers assembled the bulky and, at the same time, slim scaffolding. The metal structure was erected from the Church floor of the central nave, until getting to the windows level with a first platform. When the second platform was installed at the trusses level, and windows were removed, was assembled a temporary roof to start the discovery and the restoration of the ancient roofing system. An extreme accurate diagnostic survey was carried out to study the structure, the history and to find the best way to restore. The restorers' teams alternated the trusses interventions and the purlins and boards replacements. Based on the wooden diagnostic survey and the engineer's calculations, the decayed parts were removed and substituted (in most cases with wooden prosthesis) by classified healthy ancient wood brought from Italy. The restorations tried to maintain as possible the original materials and elements as boards and ancient iron nails. Above the wooden layers, a breathable membrane and an insulating sheet was laid out as base for the new lead sheets imported from Germany.

When the roofing slopes were made safe, external stones and internal plasters have become the new subjects of study; the walls showed a generalized decay state due to the rain water effects, humidity, surfaces deposit of atmospheric particles and microbiological attack. Technicians and restorers specialized in conser-

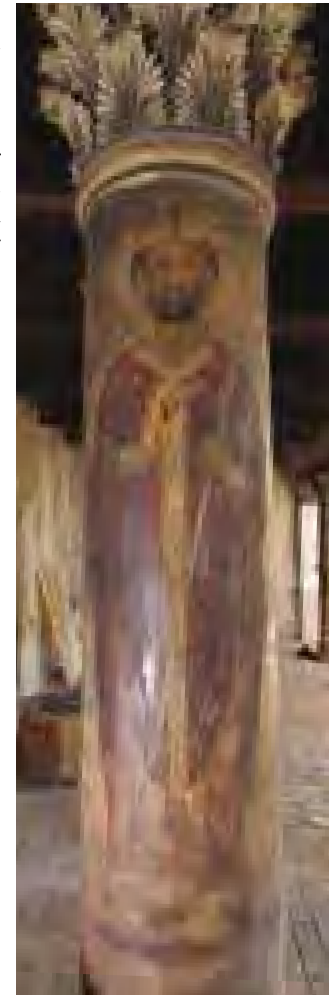
Vertical and horizontal sections of the Nativity Church, showing the roofing system and the central nave. The graphic return is one of many results achievable using the laser scanner surveying techniques that allows to obtain the highest accurate metric data for technical documentation.



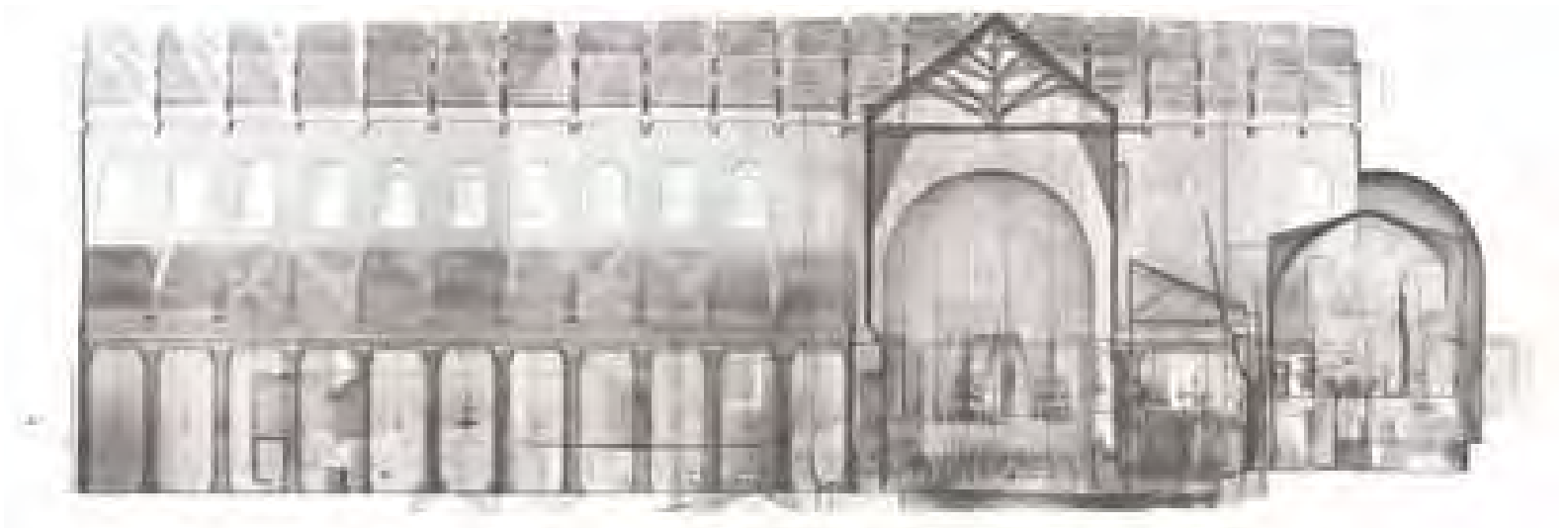
vation of stones and plasters have begun the acquisition of technical, photographic, metrical data of the Church walls. After the survey and state of conservation mapping, some tests were carried out for cleaning and grouting. Gradually the restorers proceeded with cleaning of all surfaces and removal of the incoherent materials; filling the cracks with a suitable mortar and consolidation of the most decayed parts.

At the same time were begun the Narthex works. The restoration of the mechanical proprieties of the narthex vaults was necessary, given the long wait after the

The restoration works started with the metric and phographical survey of all the artistic surfaces, (in particular : floor, columns, architraves, floor mosaics, wall mosaics, plasters). This phase allowed the necessary cataloguing for the technical documentation, and a preliminary knowledge of the Church to go ahead with the protection for scaffolding system assembling.

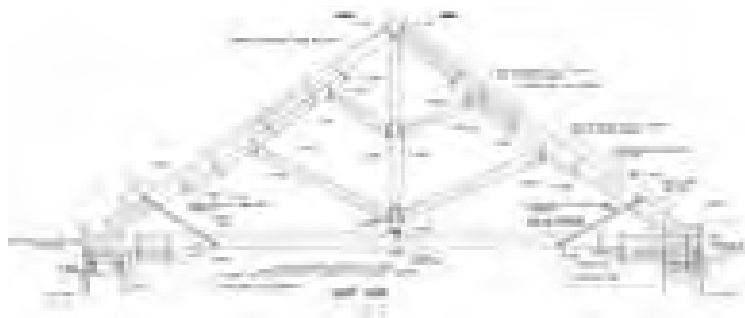


Painted columns, S. Leone Magno. The importance and the uniqueness of the decorative and architectural elements characterize the Basilica of the Nativity in Bethlehem.





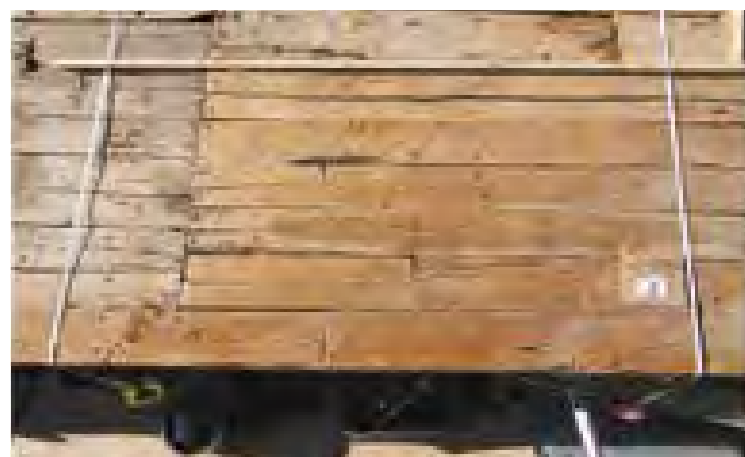
The upper pictures show the precious floor and wall mosaics of the Nativity Church. A restorer is applying a surface consolidation to protect the mosaic during the roofing works. Below: after the old lead sheets removal and the mechanical cleaning, the decayed purlins and boards were replaced with new ones (similar in age and essence) and every ancient metal connector (nails, bands,...) were reused. The pictures also show the rafter and tie-beam joint replacement with prosthesis.

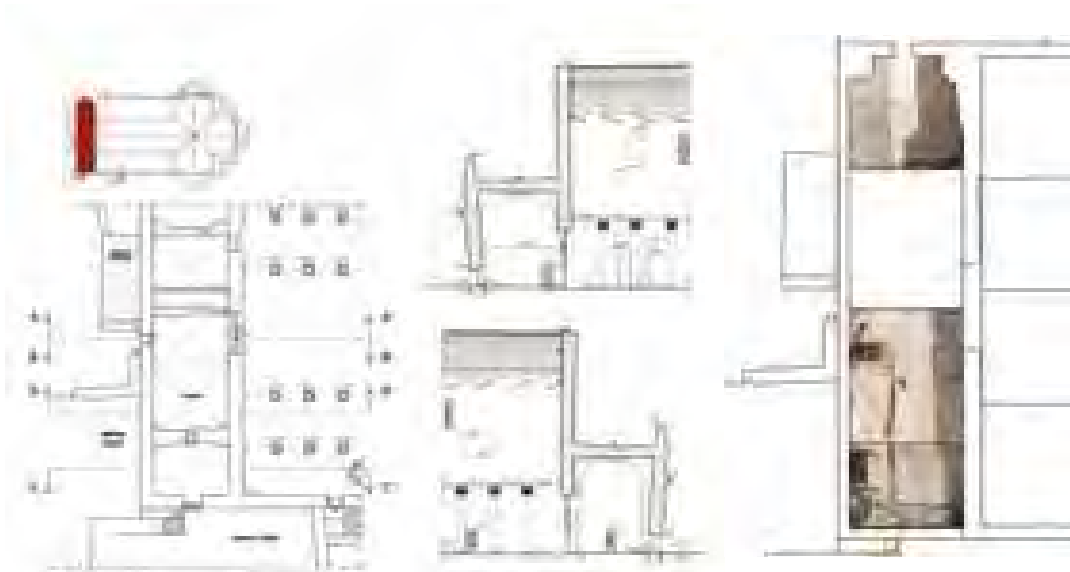


Shop drawing regarding the diagnostic and metric survey of the trusses. Each truss has been studied to verify the decay level and consequently the real necessity of the restoring intervention. The decayed parts have been replaced with wood similar in form and essence, in respect of the restoration standard (reversibility, compatibility, recognisability).

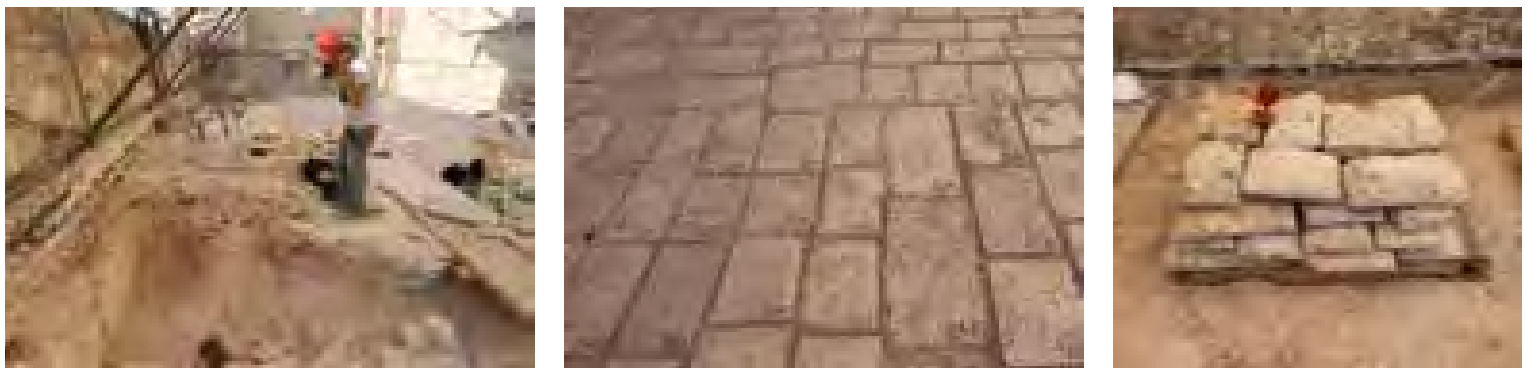
propping works made to support the vault. The narthex study was conducted without the propping disassembling; the first work phases were the inspection of the extrados of the vault in order to verify the presence of cracks and structural failures, operating an archeological excavation, cataloguing the paving stones and the evidences funded at different levels.

(G. P.)

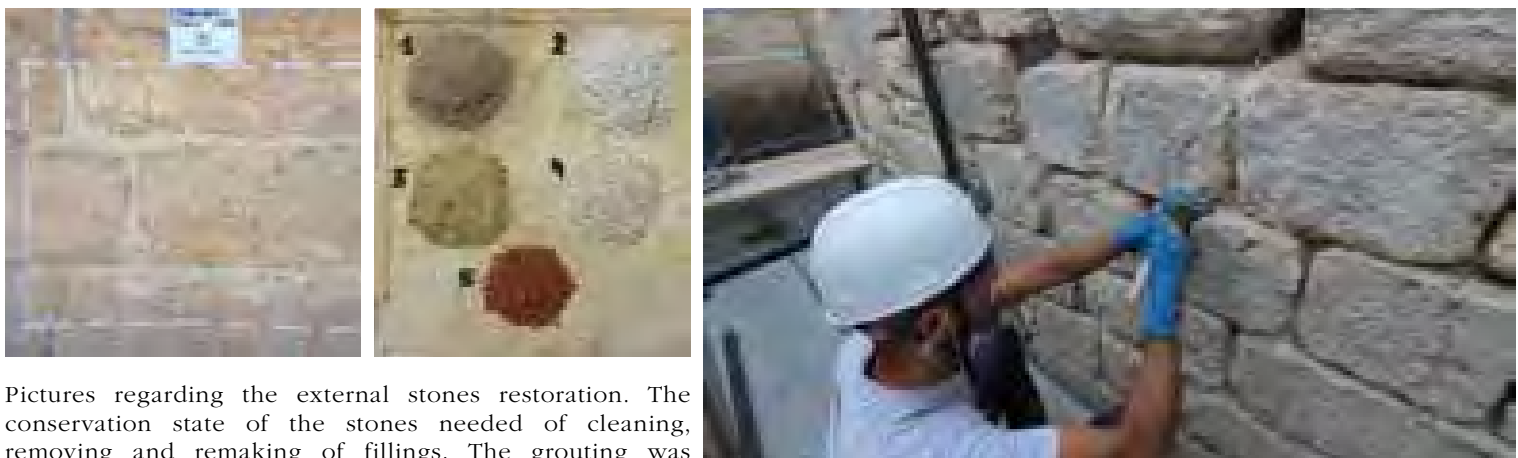




Narthex plan, sections and photo-mosaic. Narthex is located between the internal naves of the Church and the main facade, its function is to be a short atrium and wide as the Church. Actually this narthex is divided in four irregular rooms and its ceiling is made by cross vaults crating the floor of the upper terrace. The archeological excavation on the terrace of narthex, which was held in the months of August and September 2014, it was necessary to verify the condition of the vault number three, part of a system of vaults placed to cover the narthex.

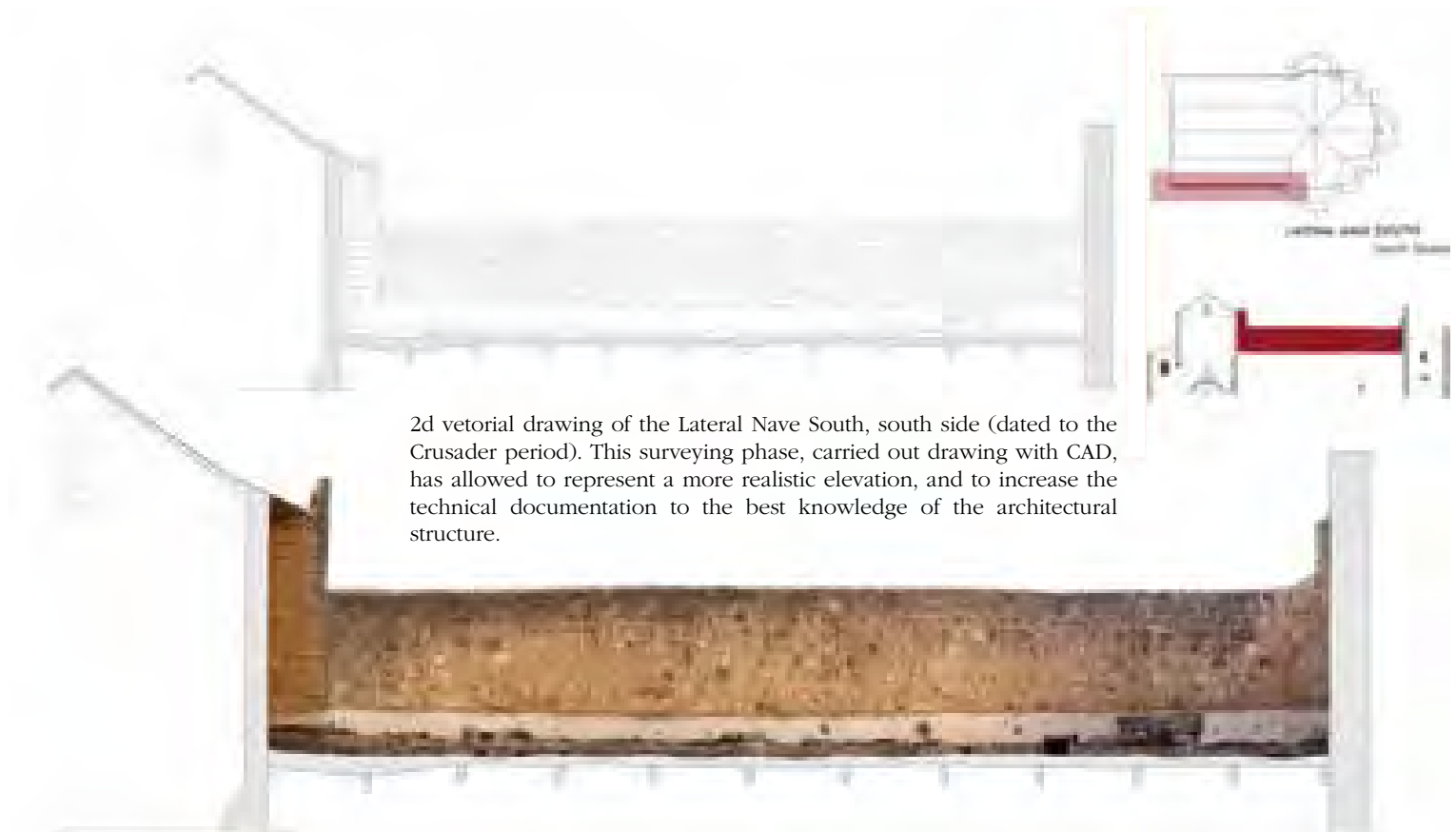


Phases of archeological excavation to study the extrados of the vault. The vault n.3, has long propped up from with a wooden structure. The removal of the covering material of the vault, in order to perform an accurate analysis of the extrados, was carried out following a method of stratigraphic analysis, to allow an analytical reconstruction of interventions performed in several centuries.



Pictures regarding the external stones restoration. The conservation state of the stones needed of cleaning, removing and remaking of fillings. The grouting was carried out using a compatible mortar similar to the original in grain and color. Before each intervention the restorers carried out the tests in order to find the suitable aesthetical and functional solution.

Removal of fillings and additions executed during previous operations with material which by nature could interfere with the stones or which had lost their conservative or aesthetical function.



2d vectorial drawing of the Lateral Nave South, south side (dated to the Crusader period). This surveying phase, carried out drawing with CAD, has allowed to represent a more realistic elevation, and to increase the technical documentation to the best knowledge of the architectural structure.

Photo mosaic of the Lateral nave south, south side. This is another phase of survey, made by a photographic survey of each part of the elevation. The photos have to be orthogonal to the wall, using the meter reference marks. When the picture was rectified, it was scaled on the metric survey, then it was retouched in order to lessen the noise elements. This kind of drawings shows the real and actual conditions of the wall, and it allows, before the restoration works, to carry out the correct maps for identifying the decay state of the stones.



2d vectorial drawing and photo mosaic of the North Corner, east side. As per the upper pictures, in this case the state of conservation can be evaluated. The chromatic alteration is due to the microbiological attack and to the rain-water action.



2d vectorial drawing and photo mosaic of the North Corner, north side. In this case the state of conservation can be evaluated. On the left side shows a whole area of loss stones, filling with concrete material.



Some steps of the roof restoration. In the upper picture, a team of restorers (carpenters) are removing the old and decayed boards on the roof. Those boards were located under a coating made by clay and straw, an ancient insulating layer. The rain water which penetrated from the old lead cracks to the boards, has created the perfect ambient for the biological and microbiological life. The restoration aims to preserve the original boards and the choice to replace some piece came always after the wood diagnostic analysis. Down: temporary roof, made by a scaffolding structure and pvc sheets, in order to preserve the workers and the opened roof from the rain water.

Left: Internal side of the Nativity Church Central Nave. All the scaffolding structure was assembled in order to don't interfere with the pilgrims and visitors passages. All the scaffolding elements came from Italy, and the picture shows all the protection measures taken for the artistic surfaces.



The architecture of Crusader castles in Petra



■ SCIENTIFIC BOARD OF THE PROJECT

STEFANO BERTOCCHI, MARCO BINI

■ PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE; DEPARTMENT OF ANTIQUITIES OF JORDAN; PETRA REGIONAL PLANNING COUNCIL.

■ WHERE AND WHEN

PETRA, JORDAIN, 1992 - 2000

■ AIM OF THE PROJECT

The main results of the survey campaign conducted, since 1992, by the Italian archaeological mission in Petra as a support to the excavations of the Crusader castles of Al Habis and Wu'Ajra (in Petra area), Shobak and Kerak, have contributed to the definition of the architecture of the fortifications systems in Middle East regions. Topographic survey, aiming to establish the general topography of the sites at a general level, has contributed also to identify building types, analysis of the technologies and types of equipment used in masonry in the Middle East, during the period of the crusades.

This work summarizes the results obtained by the research group, the objective of which is and remains that of tracing and documenting the original characteristics of the first phase of Crusader occupation in the Holy land. For this reason it was necessary to study three castles in the area of Petra with different characteristics and importance and that were built within a sufficiently small time span of the XII century, during a first stage of organization of the Jordan territory by the Crusaders. The castles of Shoubak, Wu'Ayra and Habis, are testimony of the expansionistic aims of the princes of Transjordan who consolidated the ancient “*limes*

arabicus” to prevent the danger of enemy concentration at the edge of the desert and to control the traffic between the two main seats of power, the Emirate of Damascusto the northeast and the Caliphate of Egypt to the southwest. The study was divided into various phases, from the instrumental and direct survey of the sites, to the functional analyses, to that of the construction techniques. The correct synergies and the promising results lead to the articulation of the work within the span of a decade, with each year a mission dedicated to surveys and that were almost always accompanied by an excavation campaign.

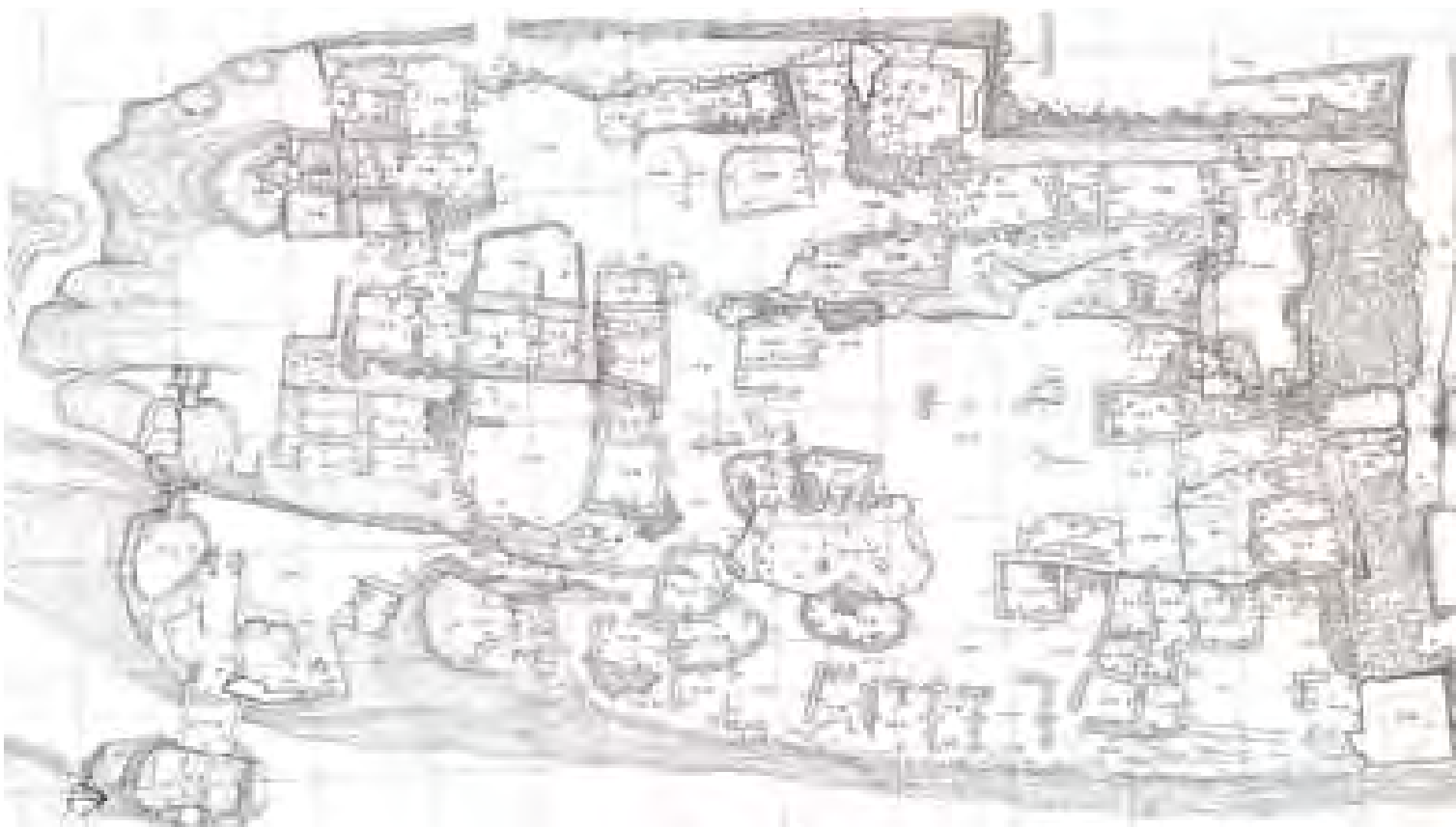




The documentation relative to entire area, the identification of the remaining walls visible on the surface and the identification of worked rock or masonry indicating certain uses such as artificial tunnels, steps and leveled areas has allowed a first interpretation of the entire area. A first phase dates to the Bronze Age (IV–III millenniums B.C.) up to the Nabataean period (until I cent. A.D.) in which the monuments and sacred area, related to the city of Petra, characterize the area as a necropolis. Portions of guided paths for

a length of 365 m with steps and leveled areas, seven large tombs in artificial grottas, various areas destined to religious functions of which two with cisterns and altar bases and another 16 containing small cisterns, groups of basins and masonry seats, have been identified.

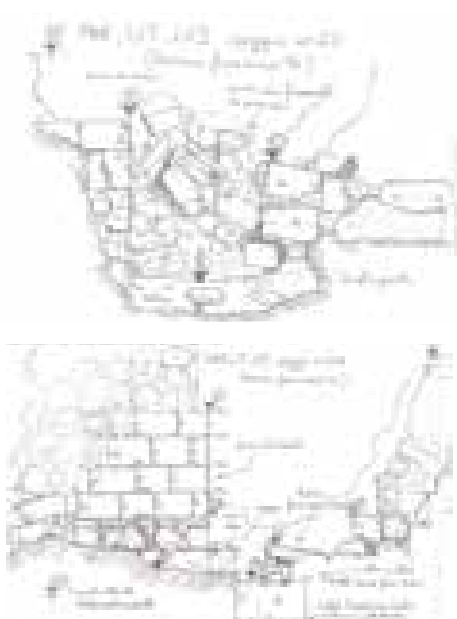
A second phase, related to the occupation and fortification of the area by the Crusaders (1116–1188 A.D.), and the subsequent, practically continuous, occupation by Bedouins, is identified with the defensive Crusader system with a perim-



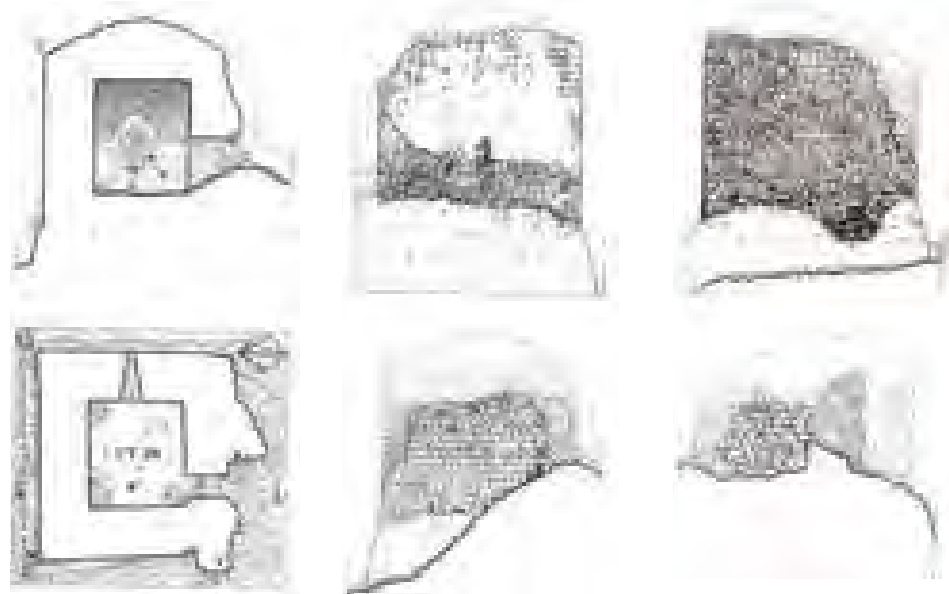


eter of 1100 m that enclosed an area of ca. 17 350 m. It included watchtowers and guardhouses with an inner citadel on the south-eastern side and an urban area placed on a level area in the southern portion. The fortress of Wu'Ayra, according to the literature, is the most extensive settlement in the area of Petra, with functional differentiations between the settlement area, the castle with its defense structures that adapt to the morphology of the terrain. Remnants of walls, placed in such a way to impede access and defend any natural routes to the castle, integrated with 11 watchtowers placed at the top of the numerous knolls in the area, have been recognized. In particular, the works seemed aimed at cutting off the ancient access routes, with long ramps ex-

cavated directly in the rock, to the higher part of the area. The south-western portion of the site is occupied by the actual castle, that had become the only access route to the Crusader structure. From the surveys it can be seen that the entire area was subdivided into various vectors according to functionality. In addition to the castle it is possible to identify the remains of numerous constructions that are placed between the castle and the walls of the southern zone. This area contains, placed near the wall, a sizeable structure that was partially built using a large rupestrian tomb and that is unequivocally of Medieval origin, as indicated by the bases of the cross vaults, the embrasure openings and by the presence of a unique *armarium* in one of the chambers.



Detail of the walls for the stratigraphic analysis.



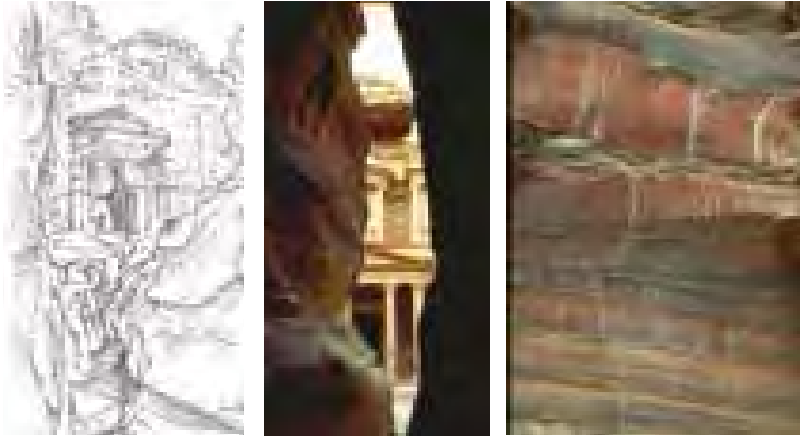
Plan and sections of the tower of the castle of Wu'Ayra.



The Al Habis Fortress, cited by the references among the defensive structures built at Petra by the crusaders immediately following the descent of Baldovino I, together with Wu'Ayra and Sela, occupied the summit of the homonymous hill, placed at the center of the ancient city. Due to its strategic position at the center of the valley, the castle shows evident signs of use before the medieval settlement; spread along the access road tombs dating to Nabataean times are well visible. From these studies emerges that construction probably began around 1116, coinciding with the period of the first crusader garrisons within the valley, defined as "novum", as it appears that it was carried out very quickly, using preexisting remains. The site was definitively abandoned by the crusader

garrison in 1188, together with the other garrisons of the area due both to a general retreat and the occurrence of several violent earthquakes, the traces of which are still visible today. The area occupied by the fortress is 84 m wide and 168 m in length. It is articulated within a reference grid that is the basis for the fortress' planform organization and defines the dimensions of the specialized defensive structures such as the towers and courtyards. Two routes, probably of pre-crusader origin, lead to the site: one from the north and the second on the southern flank of the rocky hill that rises approximately 100 m from the valley bottom. The two routes were artfully built, as for their entire length they are exposed and open to the line of fire from the fortress.

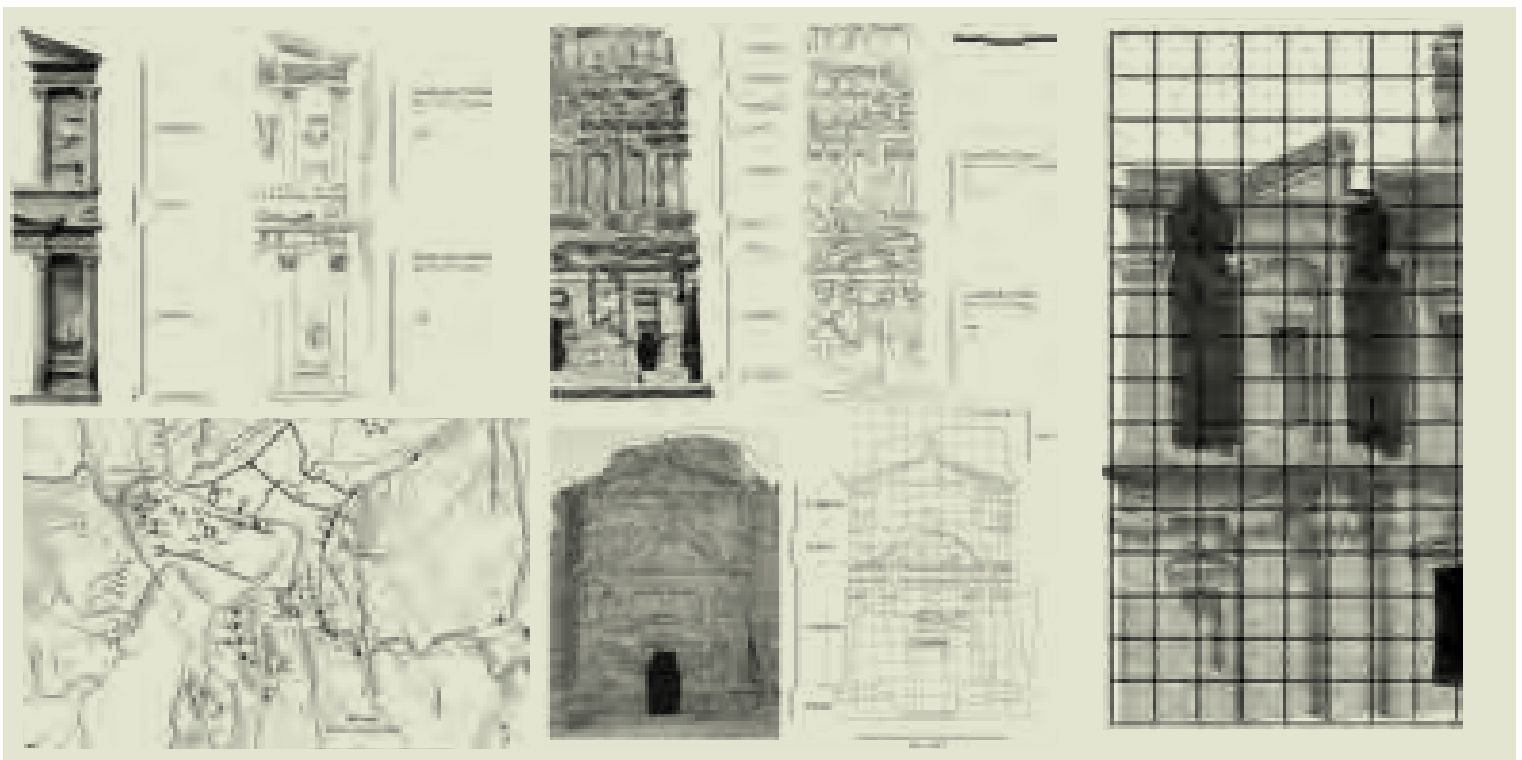




The architectural order of Petra: surveys and geometrical proportional considerations Consideration was given to some of the major monuments in the valley, which were already the object of accurate stereophotogrammetric surveys carried out since 1968 by the Department of Antiquities of Jordan with the contribution of the French National Geographic Institute, P.J. Parr (Petra Excavation Fund) and the Department of Photogrammetry and Surveying of the University College of London¹⁵. Within the present study the existent surveys were verified and integrated with additional analyses and direct measurements, directing the work towards dimensional analyses for geometrical proportional purposes. A new photographic survey was therefore carried out with digital instrumentation and, following the necessary verifications, the images were mosaicked in order to achieve an adequate resolution. Subsequently a series of figures were prepared that contributed to highlight the morphologic and geometric characteristics of the monuments.



Drawings telling the landscape of Petra and surveys of monumental tombs carved into the rock.





The Old City of Acre: the survey and documentation of cultural heritage



SCIENTIFIC BOARD OF THE PROJECT

STEFANO BERTOCCHI, SANDRO PARRINELLO, PAOLA PUMA

PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE; UNIVERSITY OF PAVIA; SHENKAR COLLEGE OF DESIGN AND ENGINEERING ISRAEL; ITALIAN EMBASSY IN TEL AVIV.

WHERE AND WHEN

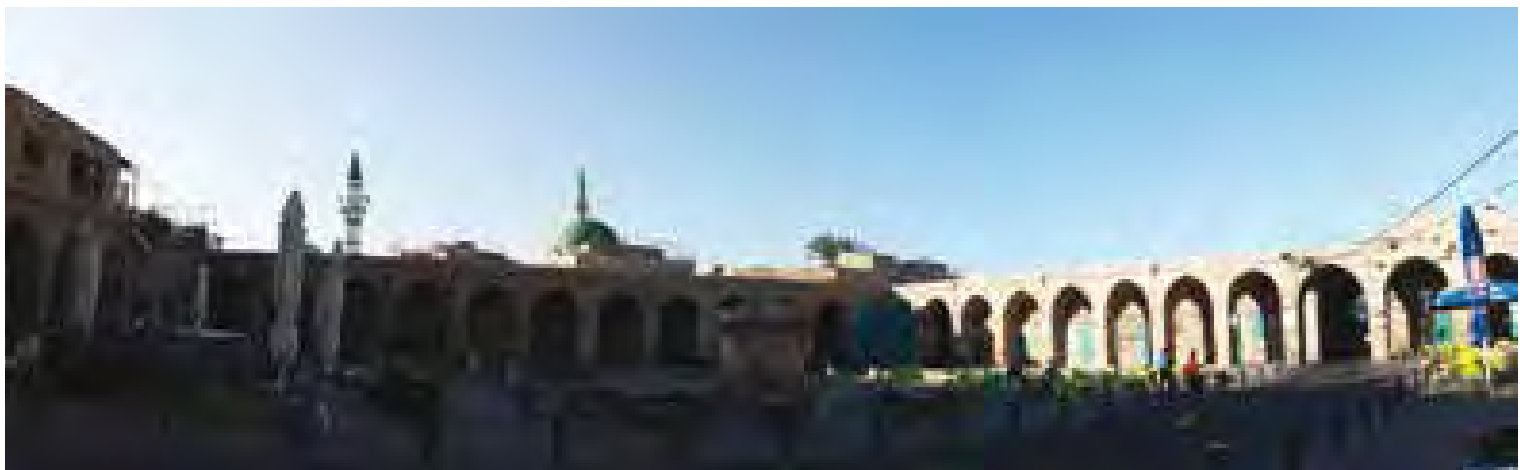
OLD CITY ACRE, ISRAEL, 2014

AIM OF THE PROJECT

The purpose of the project is to create a comprehensive digital documentation of some monuments of the Old City of Acre, site that is recognized since 2001 as an UNESCO World Heritage Site. By processing a vast number of photographs, using Agisoft Photoscan®, the aim is to obtain a completely navigable 3D model of the principal monuments of the Old City, which will allow much kind of users to study or simply enjoy the peculiarities of the big complex. The project is still in process.

Acre is a city in the northern coastal plain region of northern Israel at the northern extremity of Haifa Bay. The city occupies an important location, as it sits on the coast of the Mediterranean, linking the waterways and commercial activity with the Levant. Acre is one of the oldest continuously inhabited sites in the world. First settlement at the site of Ancient Acre appears to have been in the Early Bronze Age, or about 3000 BC. In the Hebrew Bible Akko is one of the places from which the Israelites did not drive out the Canaanites. It is later described in the territory of the tribe of Asher and according to Josephus, was ruled by one of Solomon's provincial governors. Throughout Israelite rule,

it was politically and culturally affiliated with Phoenicia. Around 725 BC, Akko joined Sidon and Tyre in a revolt against Shalmaneser V. Historically, it was a strategic coastal link to the Levant. In crusader times it was known as St. John d'Acre after the Knights Hospitaller of St John order who had their headquarters there. Greek historians refer to the city as Ake, meaning "cure." According to the Greek myth, Heracles found curative herbs here to heal his wounds. Josephus calls it Akre. The name was changed to Antiochia Ptolemais shortly after Alexander the Great's conquest, and then to Ptolemais, probably by Ptolemy Soter, after the partition of the kingdom of Alexander the Great.

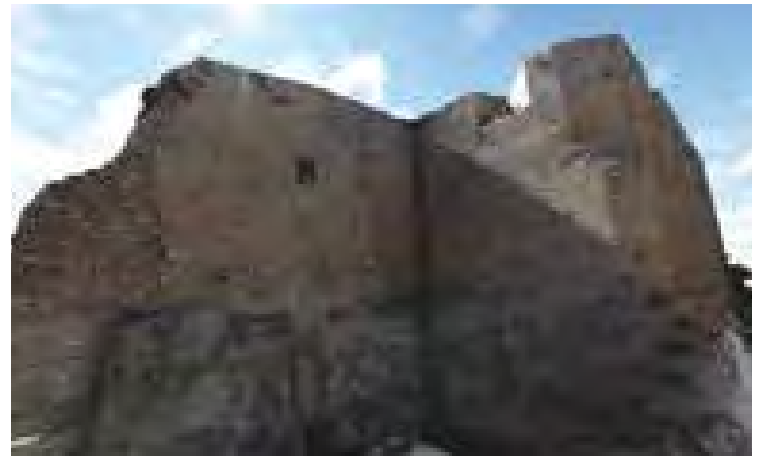




Photogrammetric survey of a part of the eastern city walls of Acre (rebuilt in the XVIII century). On the left side the acquisition process with the placement of the camera and the reconstruction process of three-dimensional model of the photographs sequence. From top the sparse cloud, a dense mesh model without textures and the final model with the application of textures. On the right, some details of the model with texture.

Strabo refers to the city as once a rendezvous for the Persians in their expeditions against Egypt. The city was captured by Alexander Jannaeus, Cleopatra VII of Egypt and Tigranes II of Armenia. Here Herod built a gymnasium. A Roman colonia was established at the city, Colonia Claudii Cæsaris. After the permanent division of the Roman Empire in 395 AD, Akko was administered by the Eastern Empire. During the 10th-century, Acre was still part of Jund al-Urdunn. Local Arab geographer al-Muqaddasi visited Acre during the early Fatimid era in 985, describing it as a fortified coastal city with a large mosque possessing a substantial olive grove. After roughly four years of siege, Acre finally capitulated to the forces of King Baldwin I of Jerusalem in 1104 during the First Crusade. The Crusaders also

made the town their chief port in Palestine. From the beginning Acre was an important link between the Crusaders and their advance into the Levant. Around 1170 it became the main port of the eastern Mediterranean, and the kingdom of Jerusalem was regarded in the west as enormously wealthy above all because of Acre. According to an English contemporary, it provided more for the Crusader crown than the total revenues of the king of England. The old part of the city, where the port and fort were located, protrudes from the coastline, exposing both sides of the narrow piece of land to the sea. This could maximize its production as a port and the narrow entrance to this protrusion served as a natural and easy defense to the old city. Both the archaeological record and Crusader texts emphasize Acre's stra-



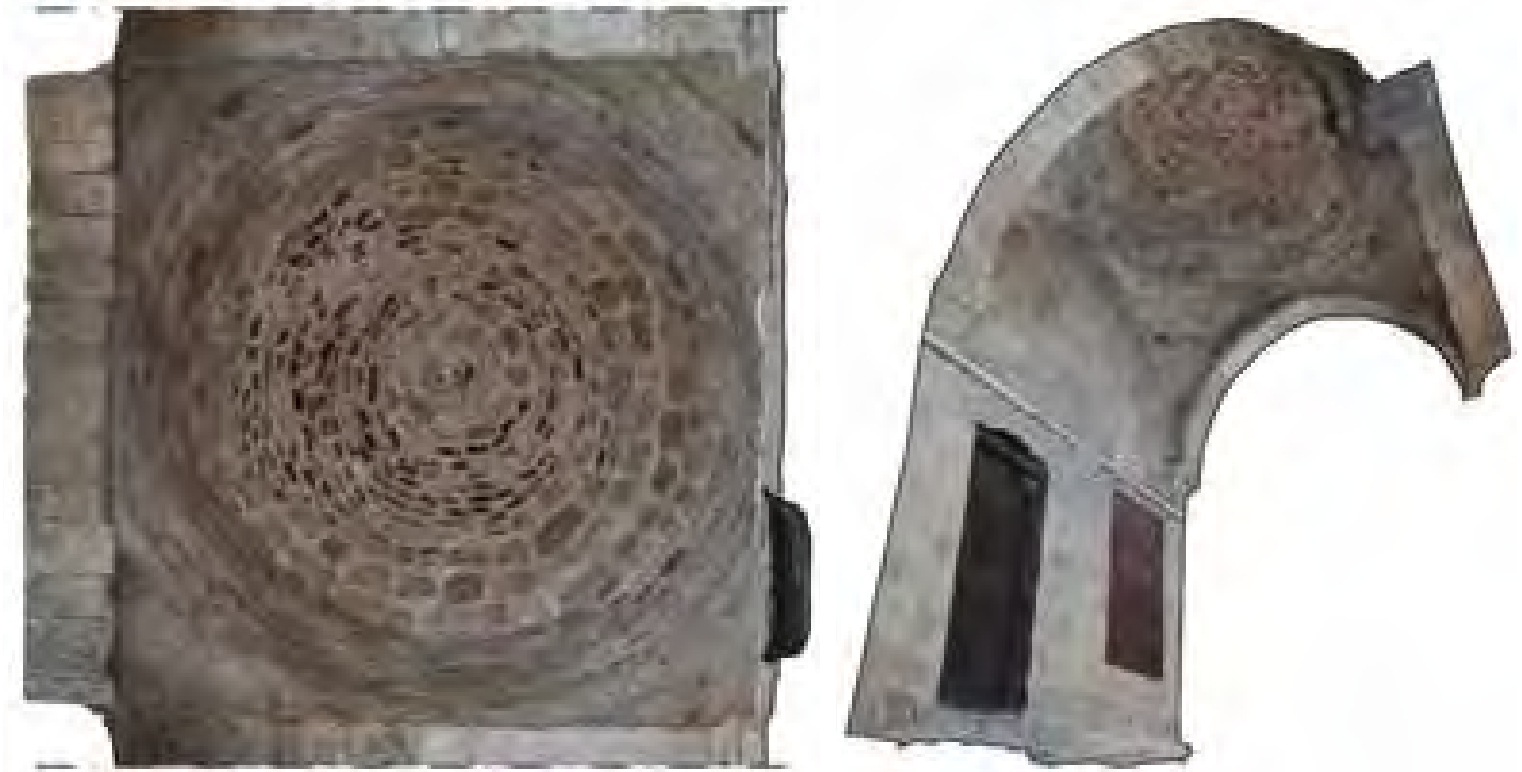
Cross-section of the medieval walls. The difficulty of data acquisition depends on the difference in the ground levels and variation in the distance from the object. The problem of Exposition north-south forced to adopted different calibrations of the camera exposure to keep the unique sequence of photos.

Above two views of the model exported in *Lumion*, real-time viewer and rendering. This program allows you to set the correct lighting conditions with the ability to enter the real geographic coordinates.



tegitic importance a city in which it was crucial to pass through, control, and, as evidenced by the massive walls, protect. Acre was the final stronghold of the Crusader states when much of the Levantine coastline was conquered by Mamluk forces. The city, having been isolated and largely abandoned by Europe, capitulated to the Mamluks led by Sultan al-Ashraf Khalil in a bloody siege in 1291. In line with Mamluk policy regarding the coastal cities (to prevent their future utilization by Crusader forces), Acre was entirely destroyed with the exception of a few religious edifices considered sacred by the Muslims, namely the Nabi Salih tomb and the Ayn Bakar spring. The destruction of the city led to popular Arabic sayings in the region enshrining its past glory. In 1750, Daher El-Omar, the ruler of Acre, utilized the remnants of the Crusader walls as a foundation for his walls. Two gates were set in the wall, the “land gate” in the eastern wall, and the “sea gate” in the southern wall. The walls





Opposite page: The three-dimensional model of the portal Khan el Faran. Elaboration of the main sections of access, the right and left box, the plant covers and the system of the time. Above: one of the vaults of the portico of the mosque Al-Jazzar (1775-1801). The survey campaign was carried out entirely with *shape from motion* methodology. Under a render of the model of the mosque Talmai.

were reinforced between 1775 and 1799 by Jezzar Pasha and survived Napoleon's siege. The wall was thin: its height was between 10 metres (33 ft) and 13 metres (43 ft) and its thickness only 1.5 metres (4.9 ft). A heavy land defense wall was built north and east to the city in 1800–1814 by Jezzar Pasha and his Jewish advisor Haim Farhi. It consists of a modern counter artillery fortification which includes a thick defensive wall, a dry moat, cannon outposts and three burges (large defensive towers). Since then, no major modifications have taken place. The sea wall, which remains mostly complete, is the original El-Omar's wall that was reinforced by Jezzar Pasha. In 1910 two additional gates were set in the walls, one in the northern wall and one in the north-western corner of the city. In 1912 the Acre lighthouse was built on the south-western corner of the walls. Under the citadel and prison of Acre, archaeological excavations revealed a complex of halls, which was built and used by the Hospitallers Knights. This complex was a part of the Hospitallers' citadel, which was combined in the northern wall of Acre. The complex includes six semi-joined halls, one recently excavated large hall, a dungeon, a dining room and remains of an ancient Gothic church.





Experimental methodologies of laser scanning and 2D restitution of the stone surfaces of “Piazza dei Miracoli” in Pisa

SCIENTIFIC BOARD OF THE PROJECT	STEFANO BERTOCCHI, GIUSEPPE BENTIVOGLIO, GIOVANNI PANCANI
TECNICAL COORDINATOR OF THE PROJECT:	SILVIA BARDUCCI
PARTNERSHIP/INVOLVED INSTITUTION	UNIVERSITY OF FLORENCE; OPERA DELLA PRIMAZIALE PISANA; MICROGEO SRL.
WHERE AND WHEN	PISA, ITALY, 2010-2014
AIM OF THE PROJECT	<i>The problem of representation for the works located in the Piazza dei Miracoli in Pisa, has been central since the earliest experiments started on the site. This research aims to give a first set of responses to the 2D representation of the exterior of the Baptistry, which, because of its cylindrical shape and its complex decorative plant, had many unknowns. The road taken focuses both on the decomposition of the individual elements and on the right approximation to represent slightly curved surfaces as flat surfaces, then reassembled in a single framework of union.</i>

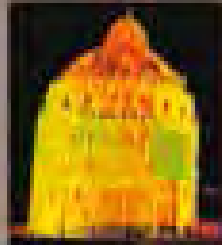
The general aim of the project is to create a comprehensive digital documentation of the Piazza dei Miracoli of Pisa and his medieval monuments. The data acquisition is done through laser scanning and photogrammetry SFM systems. The cloud of points that comes from the scanning was compiled as raw data and was part of the documentation database. The team is processed the cloud of points and extract information to make 2D as-built drawings (plans, sections and elevations), 3D renderings and 2D and 3D details of building elements of interest. First of all the

interest was focused on the The Baptistry that has a complicated morphological extension of a cylindrical shape, diversified on each of the three orders composing it and with a rich embellishment situated in relief in relation to the baptistery wall. The two-dimensional reconstruction was a tricky and complicated procedure since all the architectural elements had to be represented at life size. It was tackled by dividing the monument into the three orders and into the minimum formal elements composing it. In the first order the “minimum formal elements” were identified as the



Comparison between the two campaigns survey conducted between 2002 and 2012. The development of measurement techniques laser generated an increase of the methodologies of analysis and drawing.

Architectural survey campaign conducted in 2002.



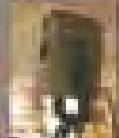
Point cloud.



Detail of the point cloud with few data.



Total Station.



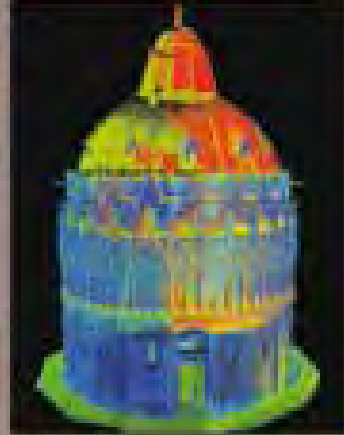
Cyrax 2400.



Cyrax 2500.



Point clouds overlapping using morphological target identified on the facade.

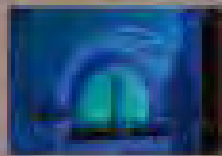


Overlapping clouds, are evident different colors resulting from the use of instrumentation time of flight (2002) and phase difference (2012).

Architectural survey campaign conducted in 2012.



Point cloud.



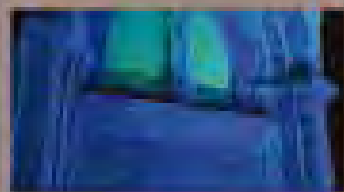
Detail of the point cloud with good resolution.



Detail.



Faro Focus 3D.



Detail of the overlapping clouds.



blind arches, the half columns and in the portion of cylindrical surface surmounting the arches. The same method was used for the second order, while for the third order the projections of each side of the polygon did not prove particularly problematic. Each minimum formal element was represented with a single chart together with the relative map and all the charts collected in a single database resulting in the overall picture visualised in the orthophoto of the entire “un-rolled” wall.

The Piazza dei Miracoli (Piazza del Duomo) is a wide walled area located in Pisa, recognized as an important center of of European medieval art; the square is dominated by four great religious edifices: the Cathedral, the Baptistry, the Leaning Tower , and the Camposanto Monumentale (Monumental Cemetery).

The name Piazza dei Miracoli was created by the Italian writer and poet Gabriele d’Annunzio who, in his novel *Forse che sì forse che no* (1910), described the square as the “prato dei Miracoli” or the “meadow of miracles”. The square is sometimes called

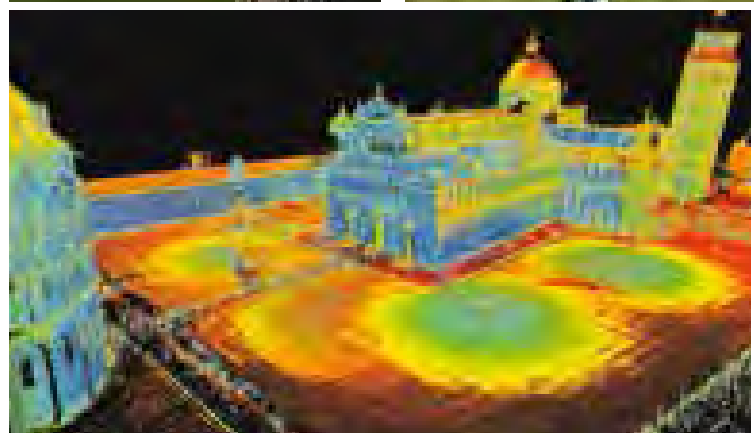
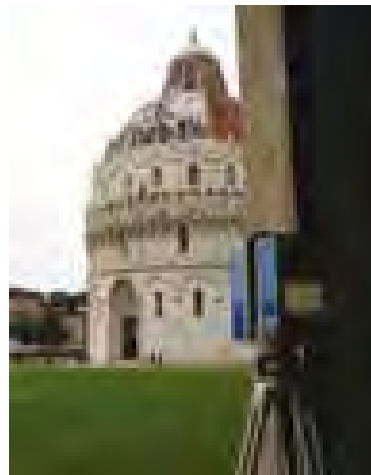
The Baptistery: dedicated to St. John the Baptist, stands opposite the west end of the Duomo. The round Romanesque building was begun in the mid 12th century. It was built in Romanesque style by an architect known as Diotisalvi, who worked also in the church of the Holy Sepulchre in the city. His name is mentioned on a pillar inside, as Diotosalvi magister. the construction was not, however, finished until the 14th century, when the loggia, the top storey and the dome were added in Gothic style by Nicola Pisano and Giovanni Pisano.



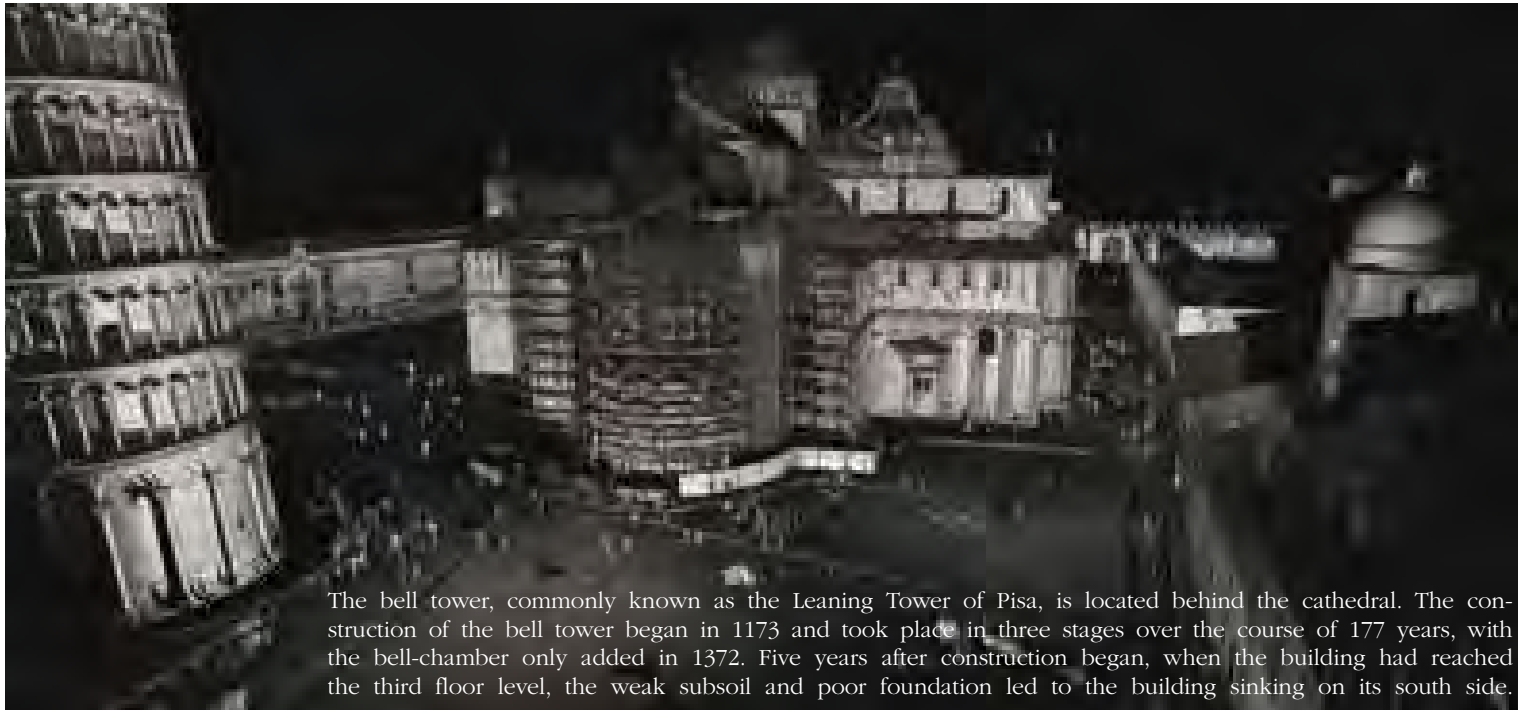
the Campo dei Miracoli (Field of Miracles). In 1987 the whole square was declared a UNESCO World Heritage Site.

The medieval cathedral, entitled to Santa Maria Assunta, is a five-naved cathedral with a three-naved transept. Its Construction began in 1064 by

the architect Busketo, and set the model for the distinctive Pisan Romanesque style of architecture. The façade, of grey marble and white stone set with discs of coloured marble, was built by a master named Rainaldo, as indicated by an inscription above the middle door.



The general point cloud of the Campo Santo, with the basilica, baptistery and the bell tower.



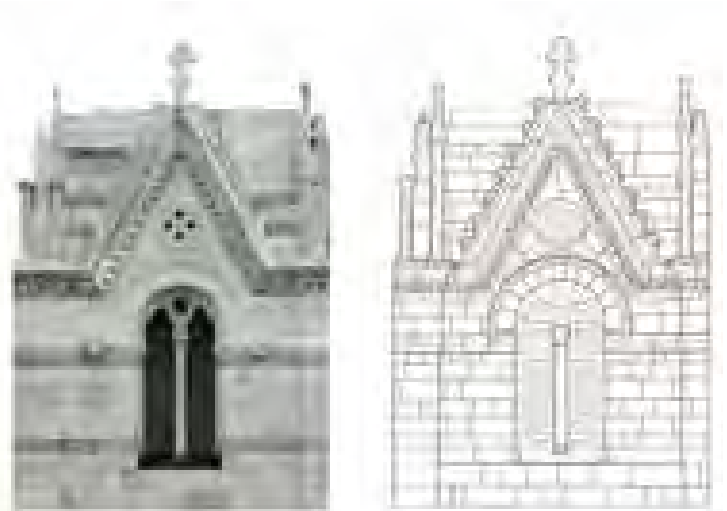
The bell tower, commonly known as the Leaning Tower of Pisa, is located behind the cathedral. The construction of the bell tower began in 1173 and took place in three stages over the course of 177 years, with the bell-chamber only added in 1372. Five years after construction began, when the building had reached the third floor level, the weak subsoil and poor foundation led to the building sinking on its south side.



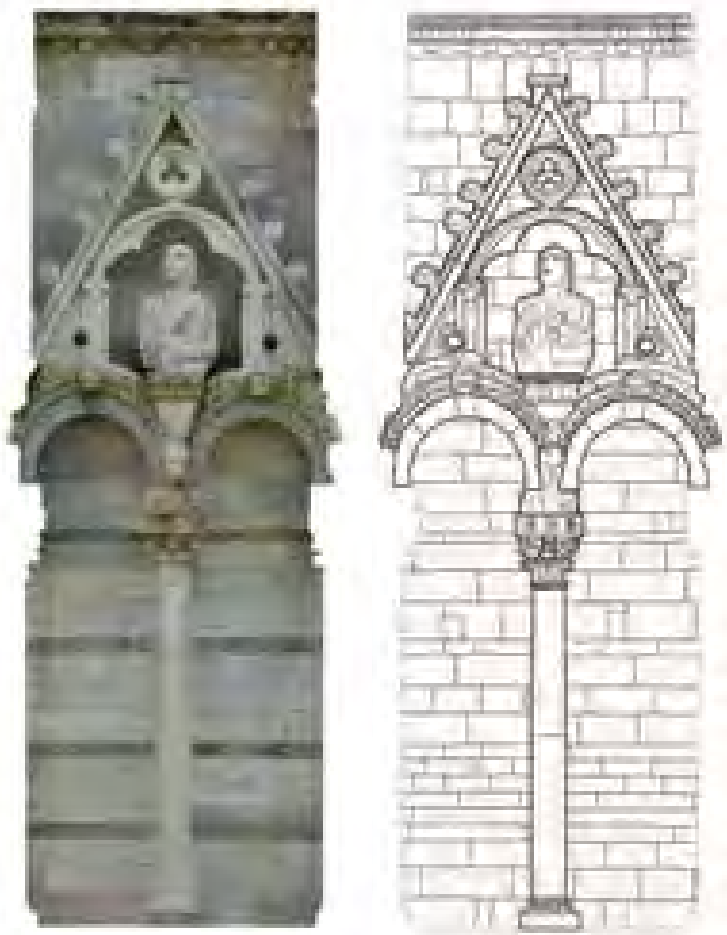
Pulpito: The elaborately carved pulpit was made by Giovanni Pisano between 1302 and 1310 and is one of the masterworks of medieval sculpture. The pulpit is supported by plain columns (two of which are mounted on lion sculptures) on one side and by caryatids and a telamon on the other: the latter represent St. Michael, the Evangelists, the four cardinal virtues flanking the Church, and a bold, naturalistic depiction of a naked Hercules. A central plinth with the liberal arts supports the four theological virtues.



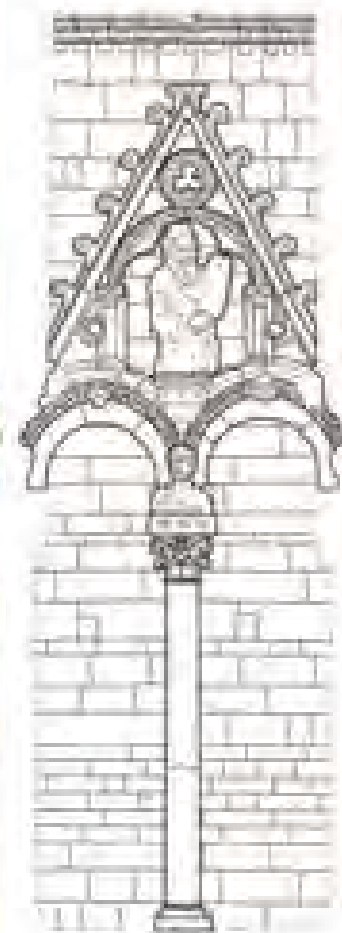
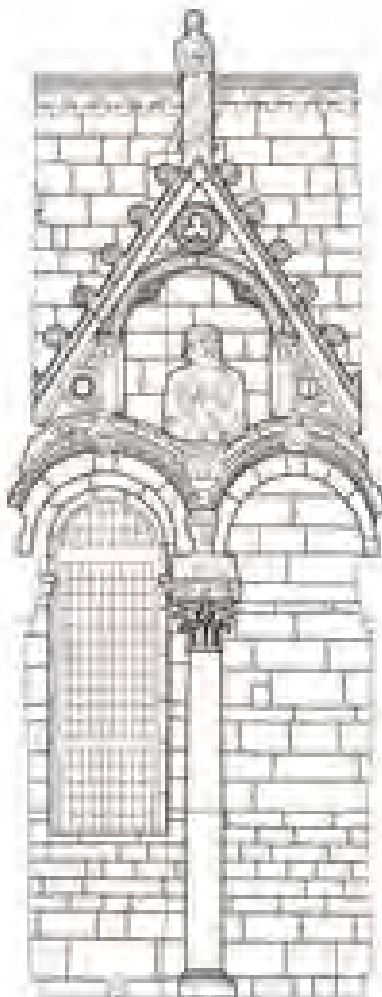
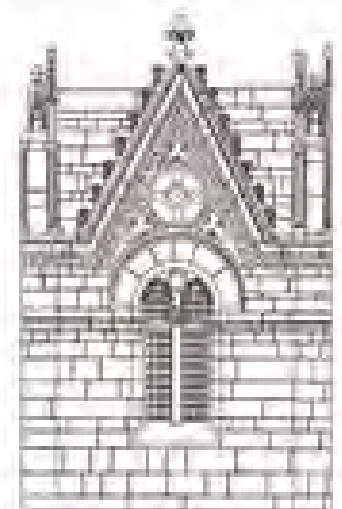
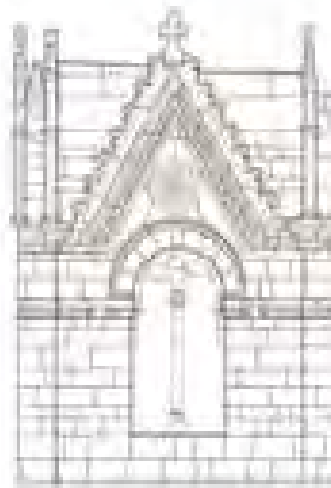
The east portal of the baptistery, located in front of the facade of the cathedral, is rich in classical decorations typical of the end of the twelfth century. The architrave with two orders above which is a copy of the Madonna and Child by Giovanni Pisano. In the lower lintel are represented scenes the life of St. John the Baptist, in the higher is represented Christ flanked by the Virgin and the Baptist, surrounded by angels. The photo mapping of surfaces has been realized for individual portions, taking into account the geometry of the individual elements and the increase of foreshortening on curved surfaces.



Drawings in "wire frame" and photographic mapping of the architectural elements of the third order.

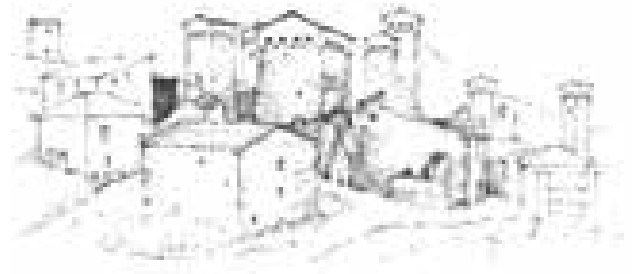


Drawings in "wire frame" and photographic mapping of the architectural elements of the second order.





Study of transformations in the villages of Upper Svaneti



SCIENTIFIC BOARD OF THE PROJECT

SANDRO PARRINELLO, MIA DEI CAS

PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE, UNIVERSITY OF PAVIA.

WHERE AND WHEN

UPPER SVANETI, GEORGIA, 2011

AIM OF THE PROJECT

The villages of Upper Svaneti contains buildings and landscapes that are part of the UNESCO Heritage site list of Upper Svaneti. By comparing the photographs of the mountaineers of late 1800, the drawing and photography become instruments of comparison for assessing the transformations that happen to the villages over the last 100 years.

The Svaneti is a historic region of Georgia located in the northwest of the country. Situated on the southern slopes of the Greater Caucasus mountain range.

The region is divided into Upper Svaneti (Mestia today's province) and lower Svaneti (present-day province of Lentekhi). The landscape is dominated by high mountains separated by deep valleys. Most of the territory that lies below 1800 meters high is covered by coniferous forests. Between 1,800 and 3,000 m the vegetation is predominantly downhill. Above 3,000 meters there are glaciers and permanent snow. With its peaks between 3,000 and 5,000 meters is the highest inhabited region of Europe. Its inhabitants, who are called Svan are identified by the Georgian populations mentioned by Strabone in antiquity. This area has for centuries been the star of many battles, losses and gains, but the isolation due to the difficulty of access has allowed the preservation of language and self-perpetuating today's customs, traditions and lifestyles consolidated and unchanged in time. In recent years, the collapse of the Soviet Union and the civil war that shook the Georgia caused

many socio-economic problems, in addition, the series of landslides and flooding has forced many to emigrate Svan. The Svaneti today offers unspoiled mountain scenery, with few villages from the characteristic stone architecture of the IX-XII century, interspersed with towers, Orthodox churches are decorated with charming medieval icons, and a few fortresses.

Vittorio Sella, the pioneer of photography in Italy, he was taken from his passion for the mountains to visit the inaccessible areas of the Caucasus in three occasions: in 1889, 1890, and 1896.

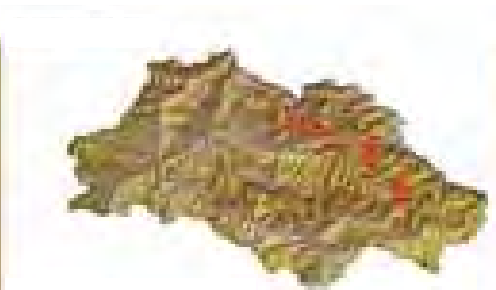
Here snapped about eight hundred photographs, being able to "stop" on his plates fleeting moments of the Caucasian mountains and most inaccessible of life of its inhabitants, opening the way for the exploration of the region that bears the name of "Heart of the Caucasus" and that contains five major mountain peaks of Georgia.

By examining the work of the Sella is clear that the shipments in the Caucasus were the turning point in his journey of explorer and photographer.





The first shipment of Sella in the central Caucasus began in July of 1889.



The second mission began in June of 1890. He arrived till Racha-Lechkumi



The third mission began in July of 1896. He arrived till Svaneti borders.



In order to deal with the experience of analysis in a conscious way it was necessary to come to the knowledge of the area before entering. There is therefore a first step, which is the study of the place as a whole, a rough knowledge that allows you to order in a more conscious elements of the landscape, and behavioral phenomena as much as possible of what you come across.

Then it gets to the heart of the territory, a journey in the footsteps of photographer and mountaineer Vittorio Sella,

which brings us the only historical evidence of change in the landscape and in the suburbs of this area in the last hundred years. To delve into the history of the place they are needed a series of interviews with the inhabitants.

Then through a comparison between the experience and the knowledge gained has been undertaken choices and evaluations. The photograph was the main tool of research for account, describe and make an immediate comparison on changes in the area.



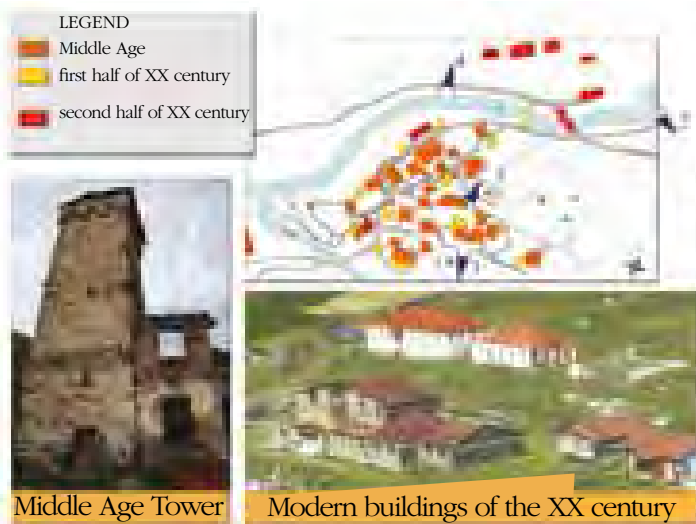
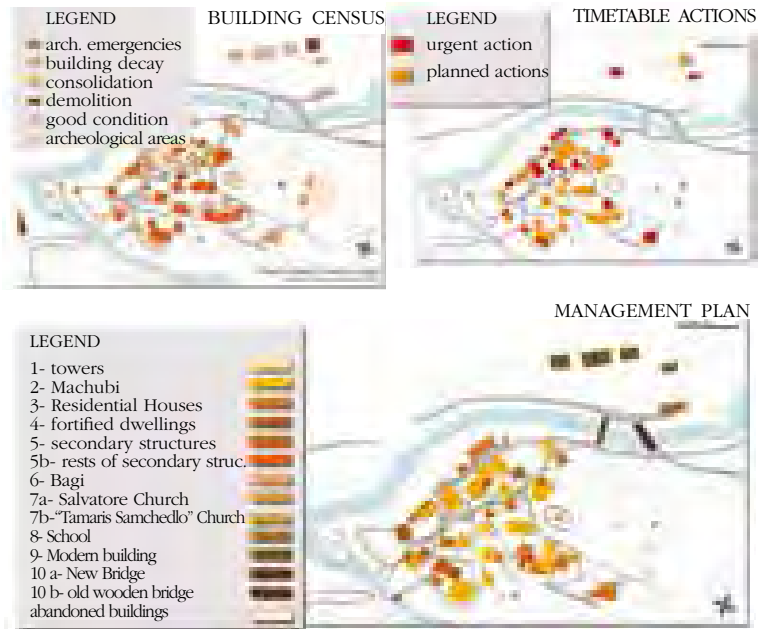
The journey of the mission of C.A.I. during the summer 2011.



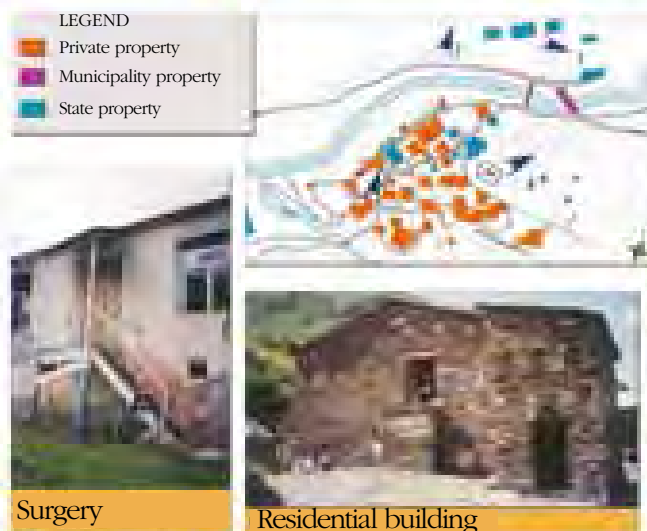
Analysis of the village landscape. Comparison between the old photos by Sella and the new image of the village.

In conclusion of research conducted and the documentation gathered on site, have been prepared a series of drawings that would allow to tell the comparison between past and present of the places, in order to understand the evolution and involution of the urban centers and the territory. Thanks to the interviews and stay in the area it was possible to understand the real needs of Svaneti and its inhabitants. The investigations led to the construction of thematic maps and schedules that summarize and describe the towns.

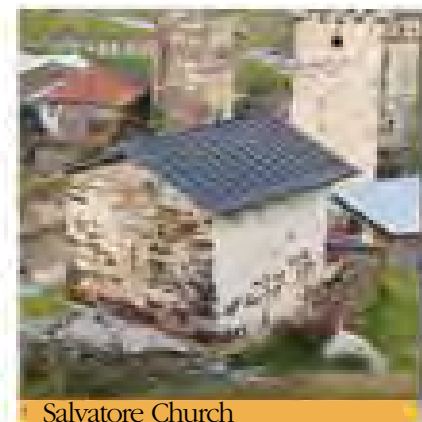
The ultimate goal is to create the data base to be integrated with GIS (geographic information system) to offer the opportunity to make comparisons on cartographic views, namely, the creation of a service structure that is able to connect and relate different scales investigation with the ability to navigate the multi-dimensionality of the survey through a knowledge of the urban environment consisting of all the elements that compose the architecture system.



Census of the building of the Ushguli village. This plan is necessary for timetable of the interventions and the management of restoration program.



Identification of public and private property. During the soviet period lots of privat propriety was bought by municipality.





Laser scanning for the monitoring and detection of plastic deformation of Palazzo del Podesta' in Mantua

SCIENTIFIC BOARD OF THE PROJECT

STEFANO BERTOCCHI

PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE; REGIONAL SUPERINTENDENCE DIRECTORATE FOR CULTURAL AND LANDSCAPE HERITAGE OF LOMBARDIA; SUPERINTENDENCE FOR ARCHITECTURAL HERITAGE AND LANDSCAPE OF BRESCIA, MANTUA AND CREMONA; SUPERINTENDENCE FOR THE HISTORIC ARTISTIC AND ETHNO-ANTHROPOLOGICAL HERITAGE; SUPERINTENDENCE FOR ARCHAEOLOGICAL HERITAGE OF LOMBARDIA; MUNICIPALITY OF MANTUA; CCC SOC. COOP.; CMSA SOC. COOP.; PIACENTI S.p.A.

WHERE AND WHEN

MANTOVA, ITALY, 2013

AIM OF THE PROJECT

Many monumental buildings of the cities in northern Italy were damaged by the earthquake happened on May 20, 2012. The Podesta's Palace in Mantova was surveyed in 2007 by the Research Center of the University of Ferrara (D.I.A.P.R.e.M.), after the 2012 earthquake, the Department of Architecture of the University of Florence was commissioned to produce a new post-earthquake laser scanner survey to be compared with the previous one for the monitoring and detection of different deformation of the related external fronts.

The monumental building complex of Podestà's Palace, connected with the adjoining Palazzo della Ragione and the Towers of Ore and Orologio, is located in the center of the city of Mantua, whose architectural heritage has been declared a World Heritage Site by UNESCO. The various buildings that form the monument of the Podestà are arranged in a ring around a system of two main courtyards and shape an aggregate which effectively separates the an-

cient medieval market in two squares of considerable size: Piazza Broletto in the northeast side and the Piazza delle Erbe in the southwest side.

The monumental building complex of the Podestà's Palace, made up of several buildings built over the centuries, has its origins quite certain; the construction of the main core of the building is infact almost certainly datet back to 1227, when it was first built on the initiative of the Mayor. In the





thirteenth century the damage caused by a serious fire necessitated a revision of the building under the direction of Guidone by Correggio, who rebuilt the oldest parts.

Starting in 1462, during the “Renovatio Urbis” promoted by Ludovico II Gonzaga, designed by Giovanni Antonio d’Arezzo and Luca Fancelli, the building was heavily transformed, giving the current form with new prospects in brick and the large windows, so making homogeneous the medieval buildings. At this time the building was raised and expanded with the new body with the fifteenth-century tower overlooking Piazza Erbe. In order to protect the structure from fire the wooden floors were replaced mostly with masonry vaults.

At the end of the eighteenth century the Podestà’s Palace was the seat of judicial court as well as prisons. The events that accompanied Mantua until the mid-nineteenth century produced a series of actions for the functional adaptation of the building, that under Austrian rule was used as a prison and Criminal Office. During this period important works were made for the construction of the Archives which has long maintained its headquarters in this building.

Since the beginning of the twentieth century the palace was neglected, except for the private use of the shops on

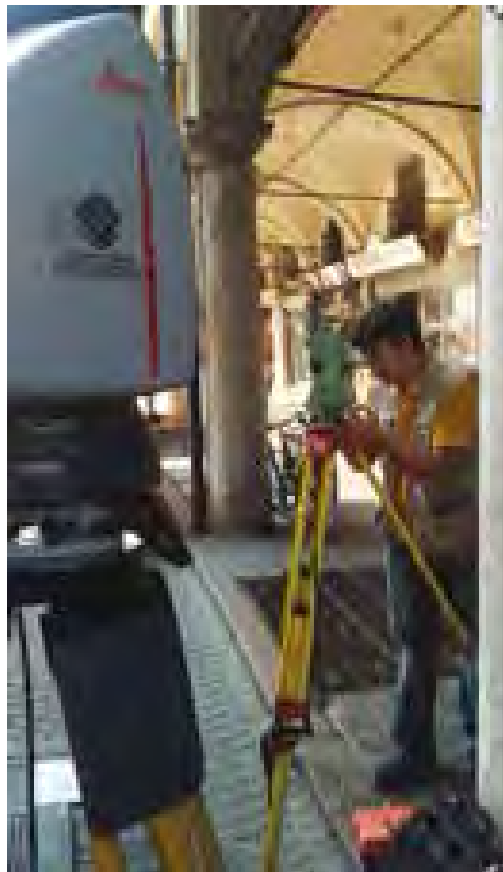




the ground floor. With the transfer of the building from the State government to the City rule in the early twentieth century, the municipal administration commissioned the Arch. Aldo Andreani to take care of a first restoration. Andreani in the twenties and forties of the twentieth century took care of the hard work of recovery in order to restore the building to its medieval identity, with an exaltation of the original forms. The restoration project wasn't completed and, more recently, in 1969, the Arch. Giuseppe Volpi Ghilardini conducted a more conservative restoration. The restoration project for new uses as administration center

and museum has intervened only in the early twenty-first century and is ongoing.

Based on the objectives and methods of work identified by the Administration of Mantua, the restoration project has been developed by taking the best solutions directly from the analysis of the general characteristics and detailed design of the building. The main requirement was to make possible the reuse of complex functional and the insertion of new different functions integrated through the realization of a new main distribution system.



A



Comparison of the deformations on the facades of the palace of the Podesta. the individual surfaces are colored with a range of colors corresponding to the value of the deviation from the vertical plane of the wall.

B



The choice of avoiding transformations or amends on the old stairs and corridors in a logic of forced adaptation privileged the insertion of a new stair and elevator that allows to serve all levels of the building and that connect Podesta's Palace and Palazzo della Ragione. The new stairs has become a solution in design and technology that has both distribution and functional significance, creating a new node integration between the buildings of Podesta's Palace and the adjacent Palazzo della Ragione. The choice of this new system of access and distribution, independent but integrated with the existing context, reflects the basic feature of the project as a process to unveil the building and declare its power of expression, adopting balanced insertion of advanced technology solutions that communicate with the old features.

The complex was hit by the earthquake that occurred in May 2012 in Central Italy; in order to complete monitoring and a knowledge of the monumental complex after the earthquake have been carried out campaigns of investigation and detection laser scanner.

A= pre earthquake representation
B= post earthquake representation
C= dimensioning of the lead out

A



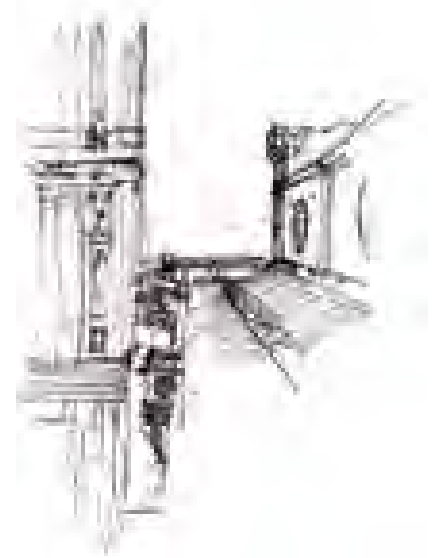
B







The external facades of the Florence Cathedral



■ SCIENTIFIC BOARD OF THE PROJECT

SANDRO PARRINELLO

■ PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE; UNIVERSITY OF PAVIA;
OPERA DI SANTA MARIA DEL FIORE.

■ WHERE AND WHEN

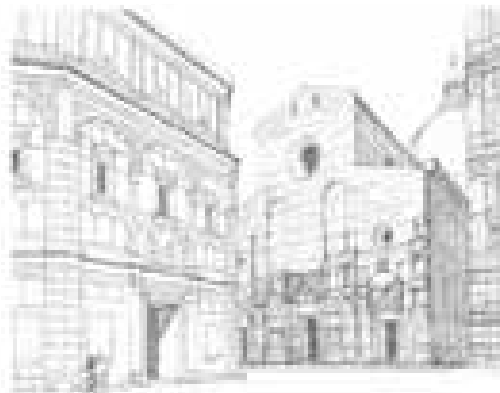
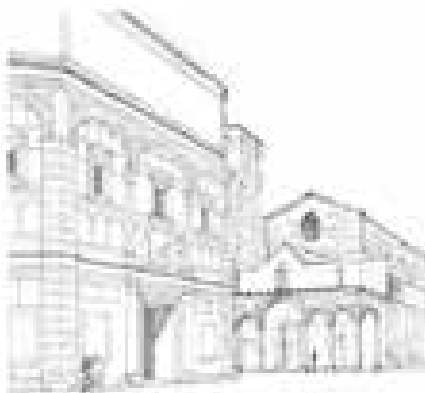
FLORENCE, ITALY, 2001 - IN PROGRESS

■ AIM OF THE PROJECT

The survey project for the documentation of the external facades of Santa Maria del Fiore Cathedral started in collaboration with the Opera del Duomo in Florence. It allowed the digitization of the entire surface of the exterior stones. Through digital survey systems and digital photogrammetric work, it has been possible to store the documented material through G.I.S. systems and to propose, through 3D modeling, a vast, interactive, scene.

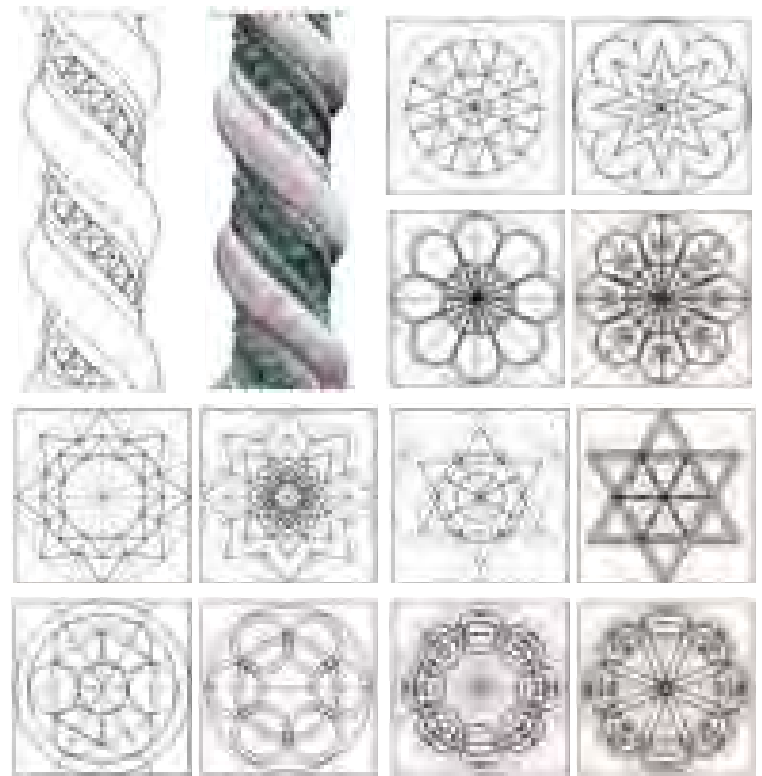
The Basilica di Santa Maria del Fiore, begun in 1296, is the main church of Florence. The religious center of Florence in the Early Middle Ages was not barycentric, because it was developed in the north-east corner of the ancient city walls. Arnolfo di Cambio, that was already engaged in an extensive program of renovation of the unitary civil and religious buildings in the city, was charged to design the new Cathedral. The work began first with the excavation of the foundations, then the elevation of the walls of the lateral sides. After the death of Arnolfo di Cambio work halted indefinitely. The project was completed structurally

in 1436 with the dome engineered by Filippo Brunelleschi. The exterior of the basilica is faced with polychrome marble panels in various shades of green (*verde di Prato*), pink (*rosso di Maremma*), bordered by white stones (*bianco di Carrara*), that inspired an elaborate 19th-century Gothic Revival façade by Emilio De Fabris. Especially in the outer covering of the fronts, a careful analysis of each of the marble portions reveals a wide diversity of style, due to the long period of time of execution from the foundation to the end of the XIX century, when it was completed with a new façade.





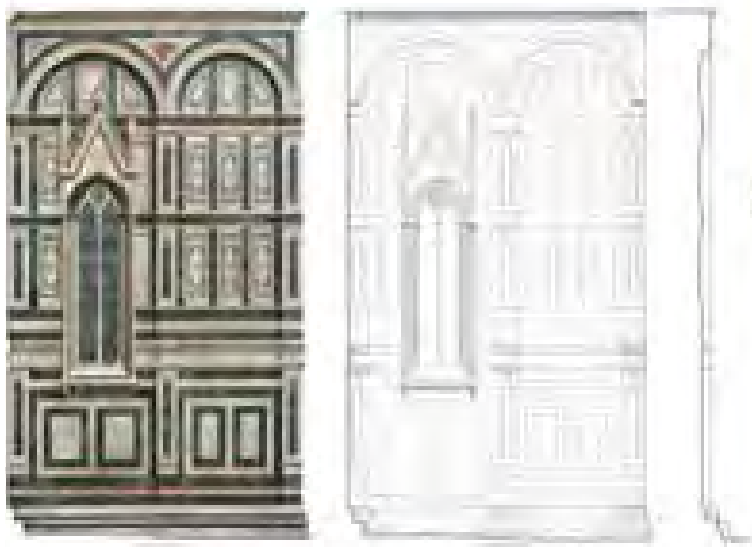
In the research project for the documentation of the external cover of the Cathedral fronts one of the most important aspect concerns the study of the details. These are in particular the decorative elements of the portals and windows of the Middle Ages and the XIX century. Since the beginning of the work the study was done for each element in its overall complexity, from the genesis of the geometric details to the codification for the database. The designs of the portals and the mullioned windows were made thanks to the basis of an accurate survey with laser scanner, topographic and traditional instrument for measuring. In order to an accurately description of the decoration it has been necessary define the geometric master of each decorative element. The methodology of this research project used photography as the main instrument for understand and codify each detail. The design of these elements was supported by a deep and complex photographic campaign that, based on a survey, has allowed us to get to define a photomosaic of each side analyzed. Only after this preparation it has been possible to proceed with the design phase of the elements, discretizing the different levels of decorative elements (from sculptures to marble inlays).



Details of the genesis of some geometric marble decorations, found on the outer surfaces that cover the Cathedral of Santa Maria del Fiore. On the left the drawing of a polychromatic windows on the side of the Church. Ink and watercolor on paper.

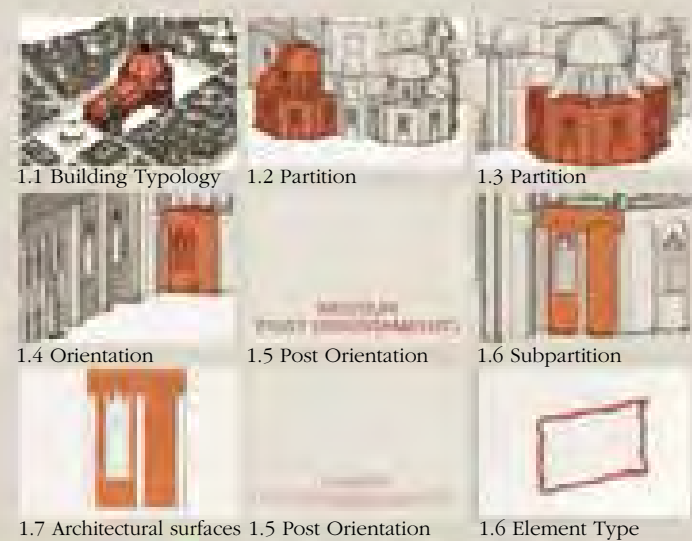


Work organization. Since the direct survey operations to the post-production graphic rendering of the product.



Bidimensional elaboration of a partition in which the geometric element of the forum was divided. Drawing in CAD and orthoimage.

organization to sets and subsets of the architectural object

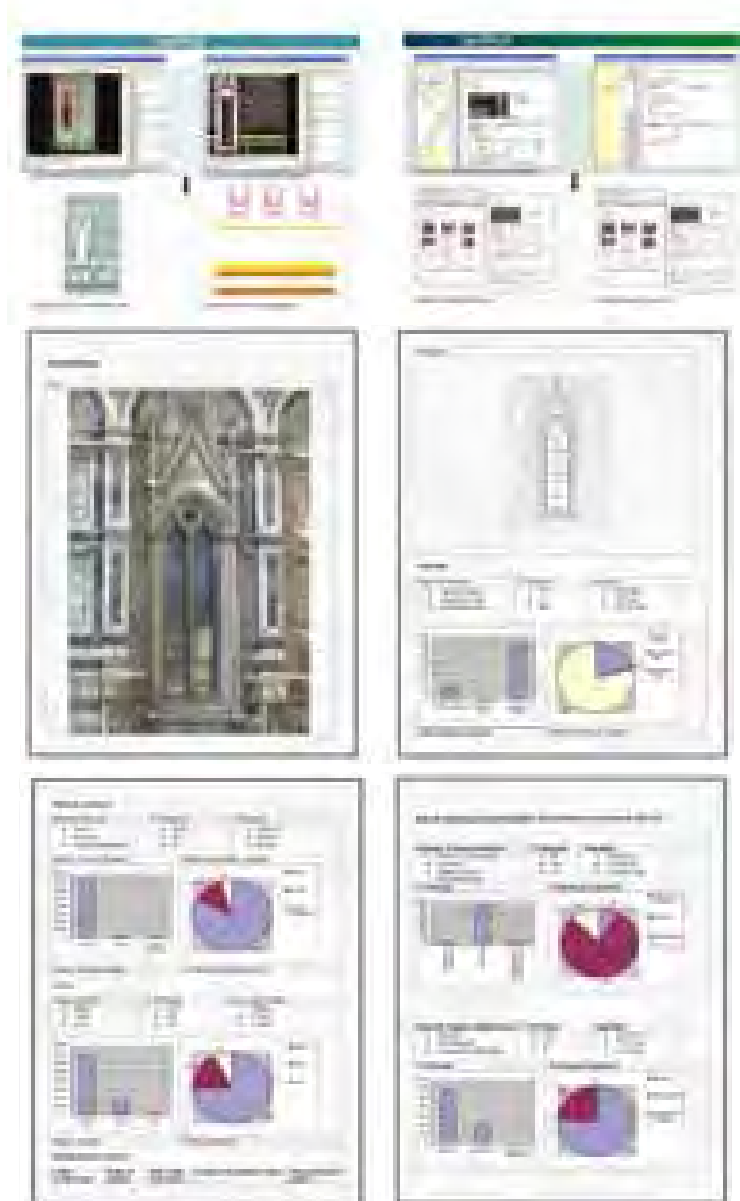


The documentation of the external marble facings includes the structuring of a very complex archive. This archive includes both the base of the survey, both the collection of all the photographs of each portion in which it was divided each edge, both the database and descriptive information s that codify each element detected.

Therefore it is essential to provide a clear and correct organization of the material in order to obtain a complete and functional database from the descriptive side. In particular the complexity was in photographic documentation of the tribune, because of the shape of the object on two levels and the glimpse of the shooting. Each tribune has been divided into sub-elements including smooth surfaces, corner solutions and windows.

Methodology of decomposition of the stone elements present in each area of the apsidal tribune. Drawing in CAD and orthoimage and codify of each inlaid marble for cataloging.

The simplification was necessary for both the organization of the archive and for the realization of the three-dimensional model: This makes it possible to interrogate the surfaces providing a physical support concrete to the database, in which each element corresponds specific descriptive kit. Each item is identified on both the 3D model and the bidimensional drawings and the corresponding bidimensional orthoimage in order to document the actual situation at the shooting time.



The archiving of each individual partition and each subset involves the construction of a GIS structure. This structure is composed of a series of numerical codes in progression, necessary to identify the building until the structure of the single element.

The database of each marble inlays and the individual elements that make up the facade of the Cathedral becomes bound to the same design of the facades in order to establish itself as a useful management tool.

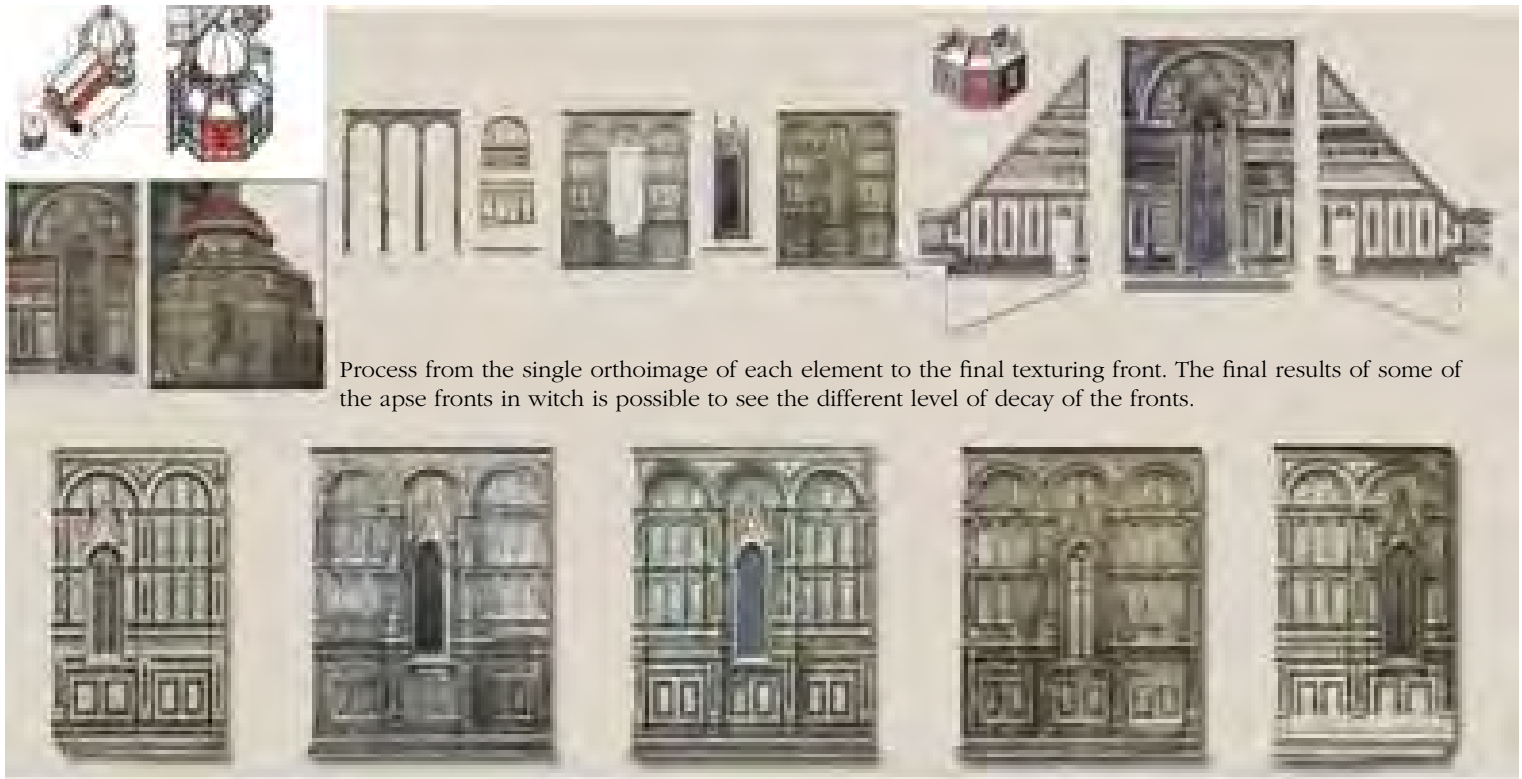
Constantly masons and laborers work on the restoration and maintenance of the Church with a continuous work that has been going on for centuries. The management system of the facades would be able to manage operations and archive developments to make possible constitute a dynamic memory of the history of the Cathedral.



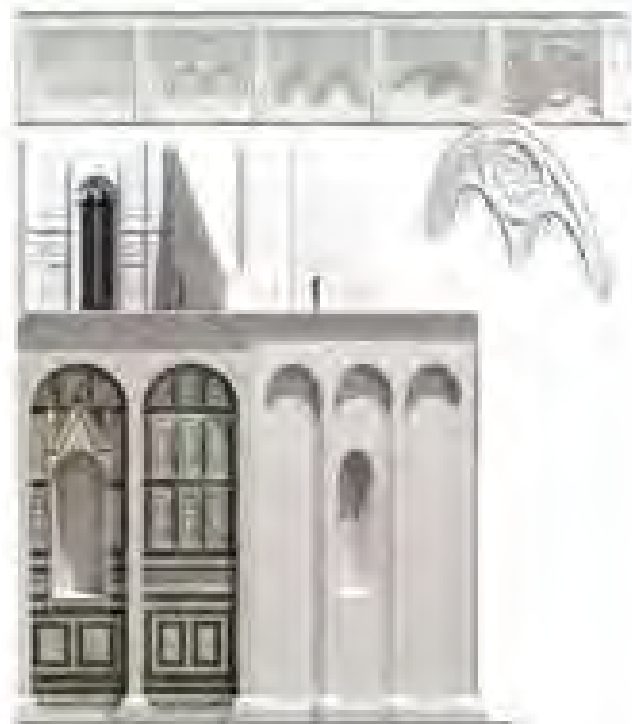
The individual cards, refer thanks to an access code, contain pictures and interactive information regarding diagnostic tests and procedures for restoration or maintenance that can be taken. From the general to the particular decomposition of the church results in a code that organizes the whole database.

Through the development of specific software, specially developed for this research and called GEST-date, it has been possible to activate the search patterns in the database that would allow you to interact on both the front and on the single sheet or marble covering without changing the database structure and transforming the information entered into graphs which allow us to compute the state of conservation of the walls of the Church.

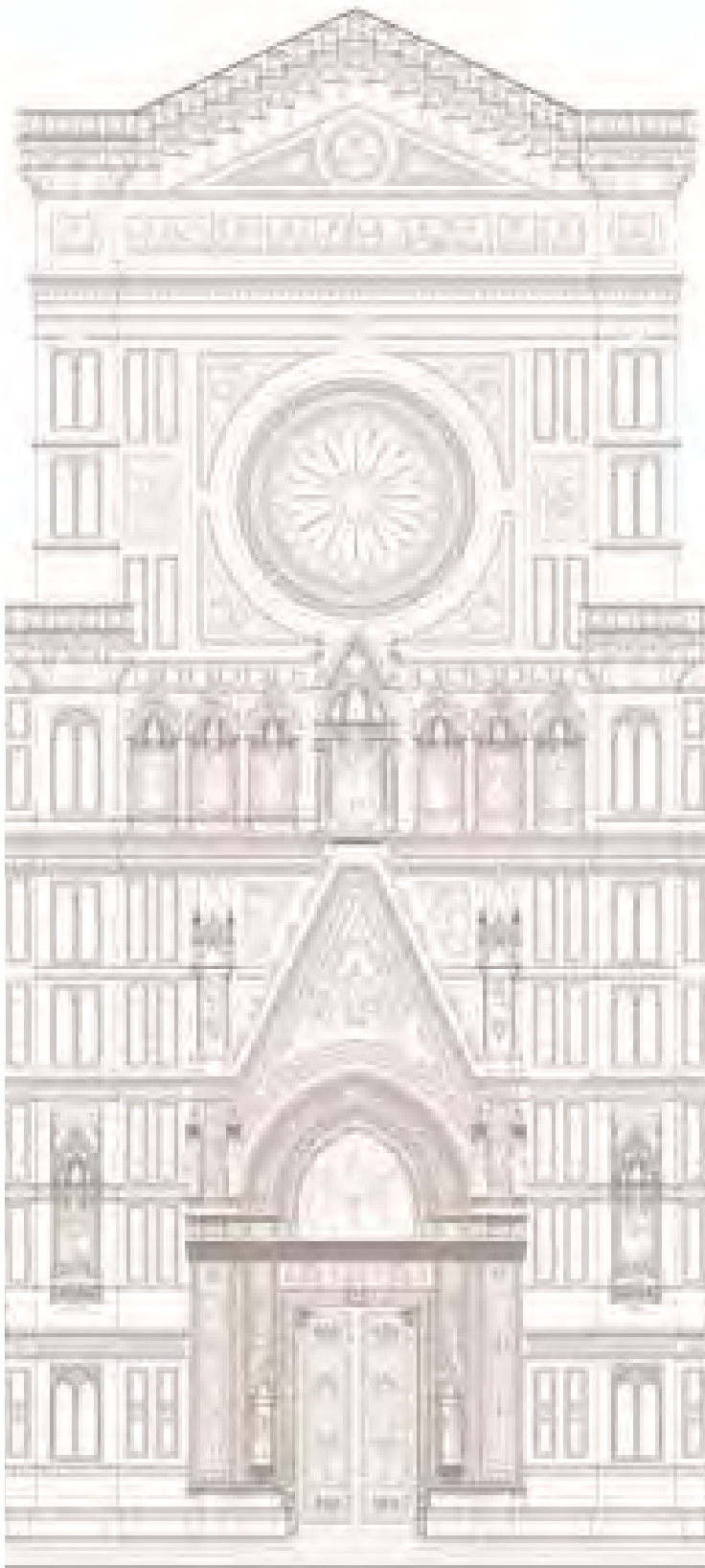
The codification system and the layout of the database. On the left side some schedules of the whole archive for the outside fronts of Santa Maria del Fiore Cathedral.



3D model process. From the general surfaces to the details of the main decorative elements.



With the model is possible to realize a web structure in which link the GIS system. It is also possible to texture the model with the original path for a virtual environment that simulates the real world.



The Cathedral of Santa Maria del Fiore in Florence has always been the subject of extensive studies aimed at defining the many aspects that make it one of the most important architectural monuments of European civilization. The work carried out for the study of the facade has involved the analysis of sixteen eighty-eight years of trying to complete a face so important to the look of the square. The analysis is started on the first unfinished front of Arnolfo to get to the current winner of the competition of nineteenth century aimed to restore the square and the Florentine Church.

To achieve reconstruction hypothesis, that describes the relationship front-context, it was essential to conduct an extensive search of iconographic documentation, then interpreted. The survey operation, performed on the current facade, had as its goal the understanding of the object which is now an integral part of the appearance of Piazza Duomo. Was also foreseen the possibility of making accessible and interactive the product obtained. This is to allow a larger number of people, not necessarily expert in the field, to gain knowledge in a simple and intuitive history of the facade, and the facade of Santa Maria del Fiore. The facades have been considered as unfinished by Arnolfo di Cambio, which formed an integral part of the appearance of the square from 1300 to 1587 (the year of its demolition), and the one painted by Ercole Graziani in 1688, remained until the construction of the current one. That is, the facades that have actually part of the image of Piazza Duomo and that, with their architectural style, have formed a variant of the current one. Subsequently, the analysis involved a number of projects of the nineteenth-century competition that have not been made, do not have any influence on the perception of urban space in Florence. To understand what impact these projects would have on the square it was interesting to see how some of the projects further away stylistically from that of Emilio De Fabris would related with today's environment of Piazza Duomo. To do this it was essential to create a virtual model of the facades of the square and then you would enter, in order to make the most truthful context.

On the left side 2D drawing in CAD software. Detail of the central portion of the XIX century main front.

On the right side the whole front in Emilio De Fabris project. The elaboration of the orthoimages mosaic.



For the realization of three-dimensional model of the various facades was first necessary to find all the documents relating to the same. This documentation consists of reliefs, painted representations and projects in china watercolors, was the base from which to rebuild the models, and in many cases has provided a wide margin of interpretation. Especially on the two fronts demolished, representations are very limited and have already been studied by experts who have developed several hypotheses about how they could actually have been built.

The realization of an interactive system and a website that allows you to make fully available the product of the architectural survey is part of a project aimed at spreading the story of a monumental work as complex and important as the facade of the Duomo of Florence.

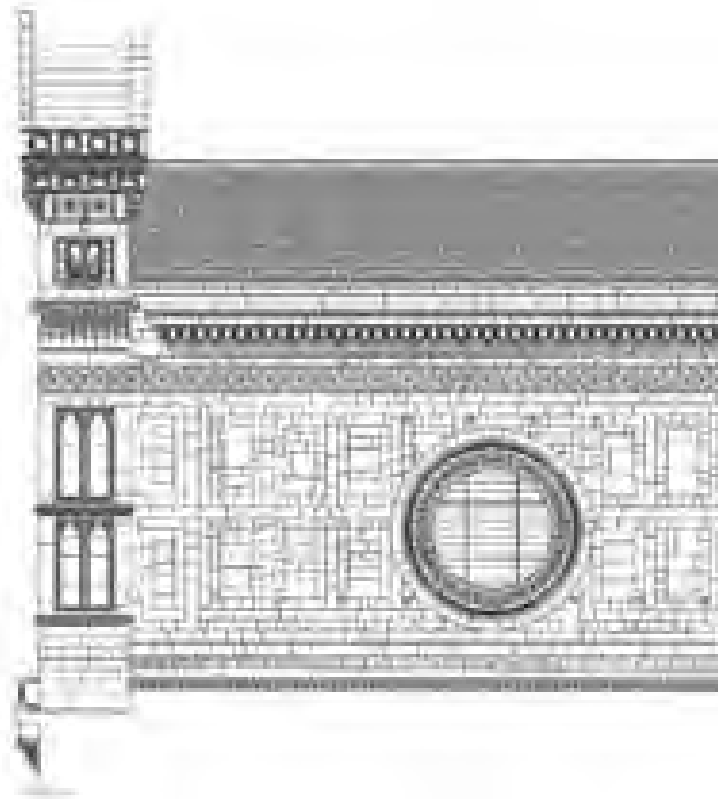


Below four rendering of four different projects presented during the competition. The simulation test wants to show how change the image and the perception of a place when something as a landmark as you know suddenly changes.

Some project of the XIX century competition.

On the top the situation of the facade at the end of the XIX century.

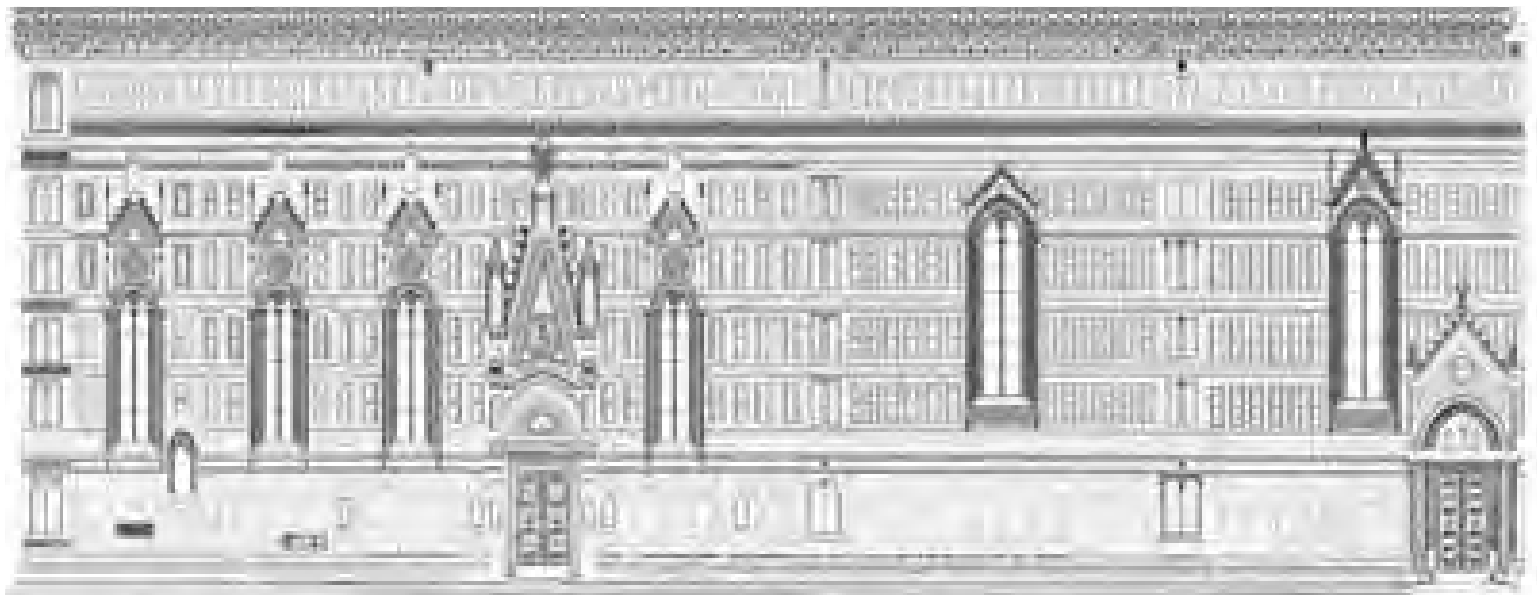


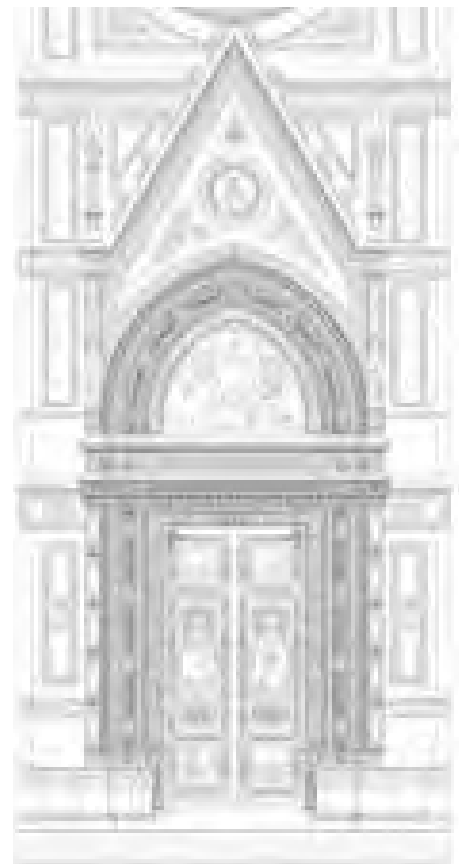
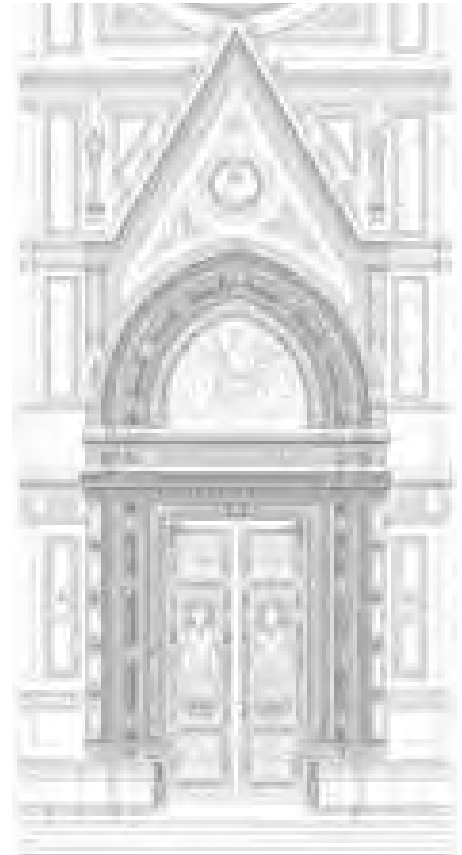


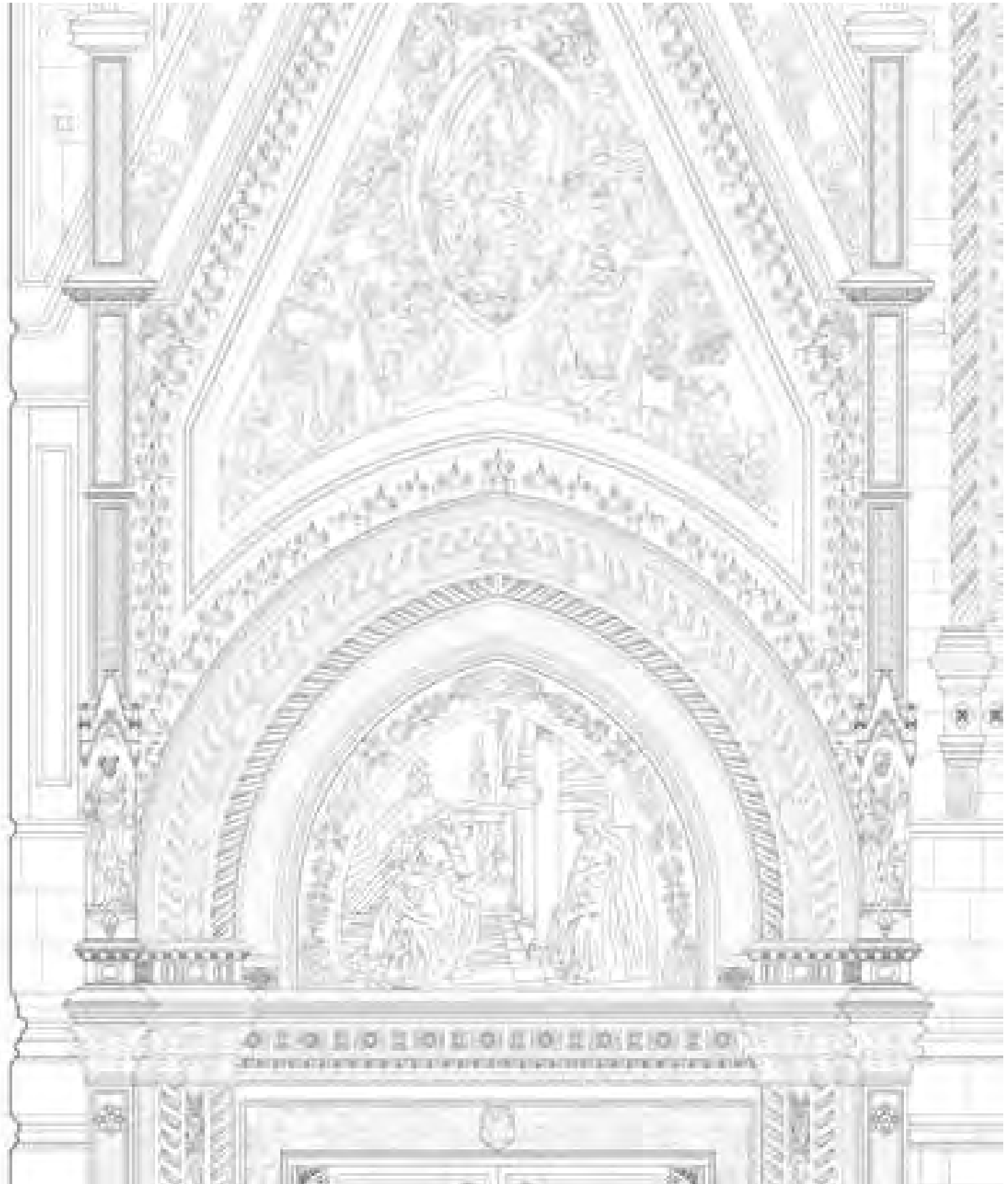
Details of stone facings in bidimensional drawings. Above, detail of the final part of the south wall, with the connection of the nineteenth-century facade.

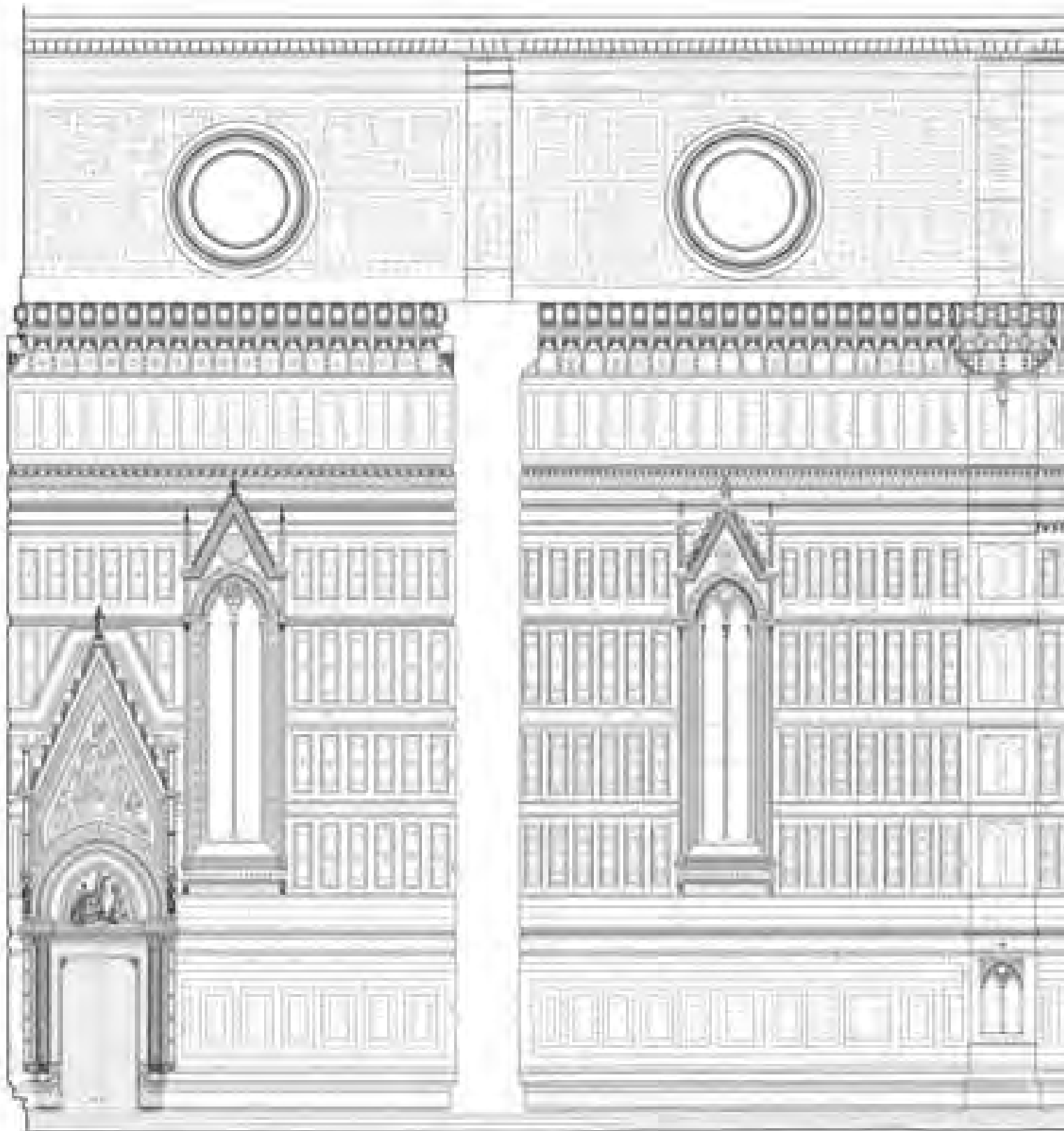
On the right side, detail of the same wall executed with an orthoimage the lower level.

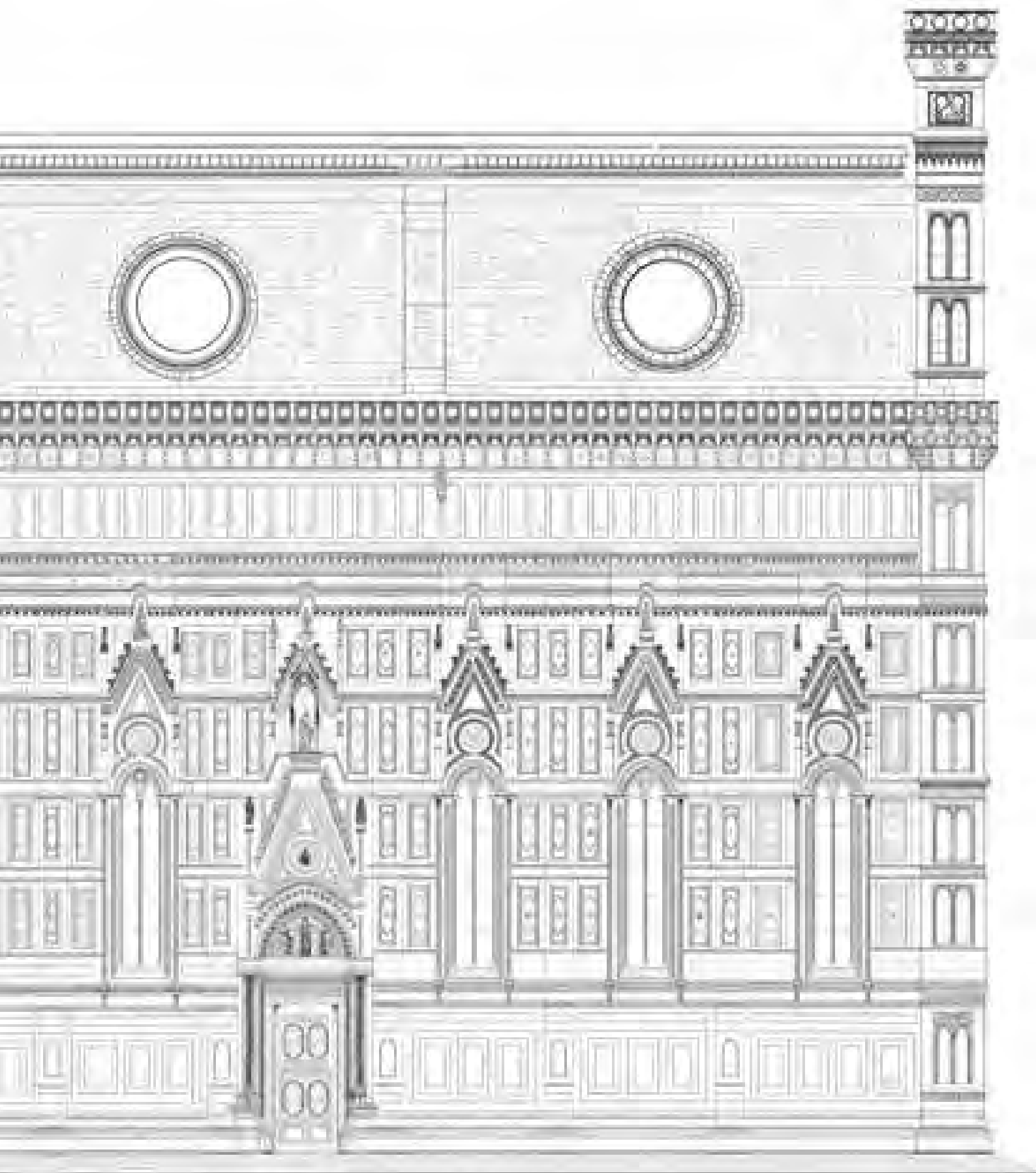
Below, a complete overview of the south wall of wire in which we see the complexity and importance of the design of the decorative element in the general overview of the front.













Laser scanner survey of Medici Villas in Tuscany



SCIENTIFIC BOARD OF THE PROJECT

STEFANO BERTOCCHI, ALESSANDRA GRIFFO

PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE; UNIVERSITY OF PAVIA; SHENKAR COLLEGE OF DESIGN AND ENGINEERING ISRAEL; SPECIAL SUPERINTENDENCE FOR THE HISTORICAL, ARTISTIC, ETHNO-ANTHROPOLOGICAL AND MUSEUMS OF THE CITY OF FLORENCE; SUPERINTENDENCE FOR ARCHITECTURAL, LANDSCAPE, HISTORICAL, ARTISTIC ANTHROPOLOGICAL HERITAGE FOR THE PROVINCES OF FLORENCE, PISTOIA AND PRATO.

WHERE AND WHEN

FLORENCE, ITALY, 2014- IN PROGRESS

AIM OF THE PROJECT

The census of the Medici villas is an extended campaign of architectural survey that relates to the study of construction technologies and systems formal composition between the buildings and parks to which it is connected. The experimentation of the most sophisticated technologies of survey through laser scanner and photogrammetry testing the efficacy of these methods on the different elements of the villa, walls, decorations and frescoes.

INTRODUCTION

All the Medici villas today constitutes an important part of the historic and artistic heritage. The villas were considered both as seasonal residences and as cornerstones of the dynastic power and emblems of the control over the territory. Geographically the villas extends from the Mugello, Medici's land of origin, to the coast and to the Port of Livorno. Between the XVI and XVII centuries, the Medici villas (castles, palaces, simple farms) were approximately forty, surrounded by gardens and farms. The history of every single property brought them to different fates; many of them are owned by the State, ideal heir of the

Grand Ducal goods, or by territorial entities of the Tuscan region, some of the villas are private. In 2013, fourteen of them entered the list of the UNESCO World Heritage as a serial site, the 49th in Italy. The "Medici villas and gardens in Tuscany" site comprehends: Boboli Garden, Villa of Castello, Villa of Petraia, Villa of Careggi, Villa of Poggio Imperiale, Villa of Cafaggiolo (Barberino del Mugello), Villa of Il Trebbio (San Piero a Sieve), Garden of Pratolino (Vaglia), Medici Villa in Fiesole and Villa of Cerreto Guidi (Florence), Villa of Poggio a Caiano and Villa of Artimino in Carmignano (Prato), La Màgia Villa in Quarrata (Pistoia) and Palace of Seravezza (Lucca).

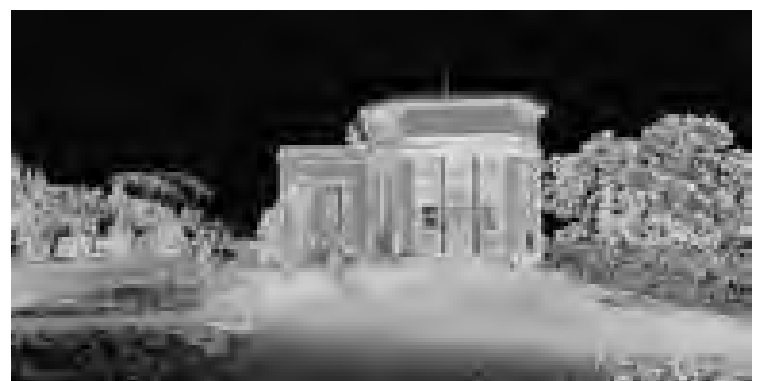


Villa of Petraia (named after the stony land, where the villa is built) overlooks the Florentine plain from the Morello Mountain and dominates the access ways to the northeastern entrance to the city. In fact, it is composed by a high sighting mediaeval tower, surrounded by the Renaissance villa and the garden, linked to Cosimo I de' Medici and his son Ferdinando I's commission. During the eighteenth century, when the Medici Dynasty ended, the complex changed owner. The Lorena family, the new owner, made some changes to the garden. With the Unification of Italy, during the nineteenth century, Florence became the capital City and the complex became the country residence of Vittorio Emanuele II of Savoy. He lived here with his wife, Rosa Vercellana, known as Bella Rosina. During the last decades the villa was transformed into a national museum and, in 2013, it became part of the "Medici villas and gardens in Tuscany" site, part of the UNESCO World Heritage.



The garden

Regardless the many changes made during the centuries, the frontal garden stayed similar to the general lines of the Renaissance style. This is witnessed by Giusto Utens' lunette, inside the museum. During the 70s of the sixteenth century, the hill underwent to big excavation works, which regularized the pendency and organized it in three sloping terraces. Every terrace is characterized by its own architectural design. The inferior one, named "Parterres", develops on a median axes with a candelabrum fountain built on its center; the citrus alternates to low-height regular-shaped bushes with seasonal multicolored blooms. The second terrace, the "Vivarium", has a big rectangular pool, water reserve of the villa and of the garden, once it was also used to raise fishes and maybe shrimps as a food source. The last terrace is named "Figurina", because of the presence of Giambologna's Fiorenza (original of the 1580 ca. now located in the inside) above the fountain, transported from the adjacent Villa of Castello in 1788. The flowerbeds, surrounded by terracotta leaves, belong to the Savoy period. This small pavilion, built before 1872, follows the nineteenth century style (in fact it is composed by brickwork, glass and cast iron) and was prepared as a relax place.



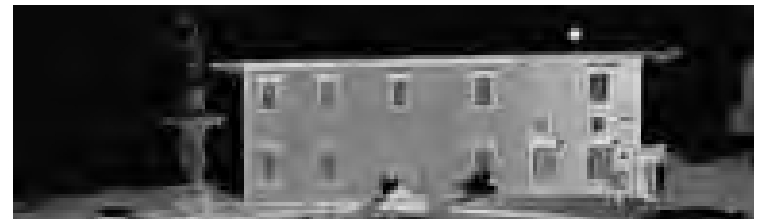


Acquisition camera for the construction of the three-dimensional model of the fountain in the park. SFM technique allows to generate point clouds that can be integrated with those produced by the laser scanner.

The villa

Villa of Petraia imposed itself as the model of the villa with tower, replied in many examples in the Tuscan country. The outside, simple and linear, does not oppress the polychromies of the inside courtyard frescoed by Cosimo Daddi, at the end of the sixteenth century, with episodes of the conquer of Jerusalem, and by Baldassare Franceschini, during the seventeenth century, to celebrate the Medici family. In the Savoy period it became a party room. In order to host the dancing, organized in 1870 for the marriage of one of king's son, a skylight made of glass and cast iron covered the big central space. A precious chandelier was hanged to the skylight. In addition, Venetian mosaic floor, based on the surrounding frescos, was posed on the ground. The entire decorative complex resulted extolled, anticipating the fusion between the existences of many different historical periods present in the environments distributed on the two floors. In these spaces the Grand Ducal collections mixes to the furniture placed under King Vittorio Emanuele II.

(A.G.)





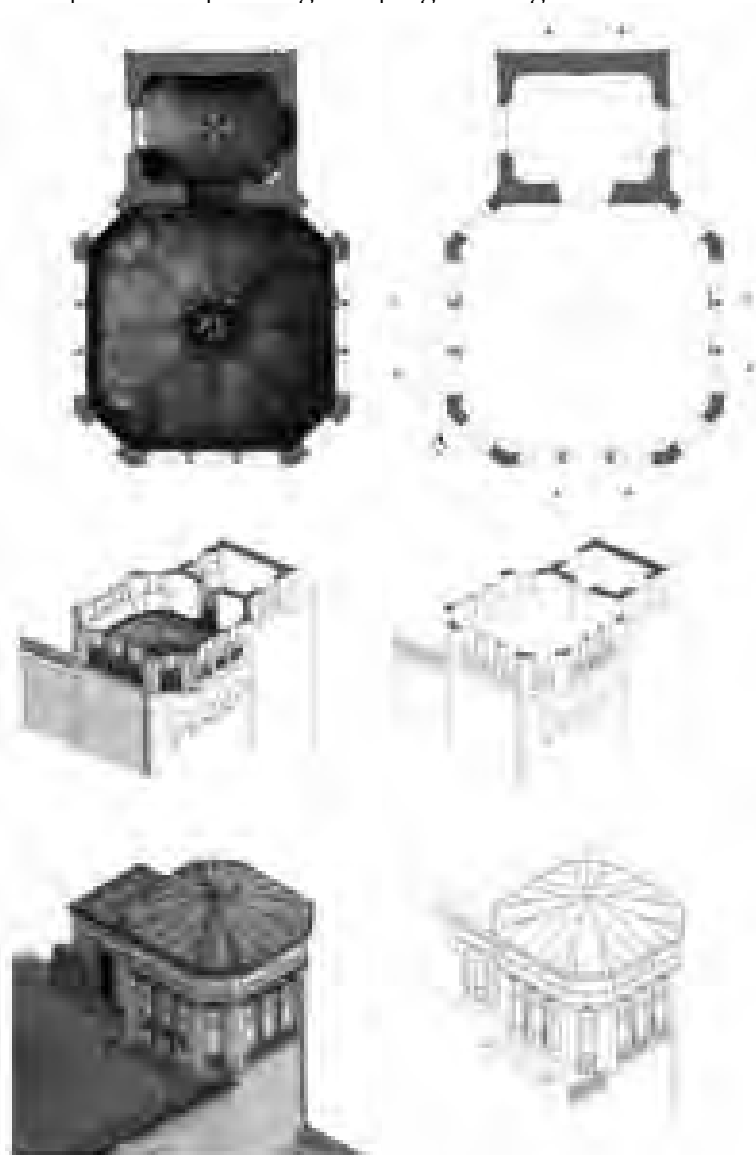
Some images from the coloured point cloud from 3D laser scanner survey of the inner courtyard of the Villa Petraia with seventeenth century frescoes by Giovanni da San Giovanni and Volterrano.



Graphic design from the model extracted from 3D laser scanner survey of the small building of the nineteenth century Belvedere Coffee-House on the edge of the upper garden of Villa Petraia.



The issues related to the preparation of the “management plan” of the sites that have been recognized as a World Heritage Site protected by ‘UNESCO, requires to the institutions and administrations holders of such shareholders “a cycle of planning, implementation, monitoring, evaluation of corrective actions” that meet the requirements and guidelines UNESCO. The Laboratory of Survey has proposed significant contribution on the topic of digital survey of the system of the Medici villas in Tuscany, recently became part of the World Heritage List, starting from Villa Petraia. The cataloguing and documentation of the structures and of the environmental system of the Heritage objects is one of the basic aspects for the proper management of monitoring and of the prospects for development. The survey, with the contemporary digital methods, in addition to diagnostic and monitoring, are the elements that make up the basic steps of a process of planning and programming of conservation.







Survey and 3D database of Michelangelo's architectures in Florence

SCIENTIFIC BOARD OF THE PROJECT

STEFANO BERTOCCHI, PAOLA PUMA, MARCELLO BALZANI

PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE; UNIVERSITY OF FERRARA; SOPRINTENDENZA SPECIALE PER IL POLO MUSEALE FIORENTINO; SUPERINTENDENCE FOR ARCHITECTURAL, LANDSCAPE, HISTORICAL, ARTISTIC ANTHROPOLOGICAL HERITAGE FOR THE PROVINCES OF FLORENCE, PISTOIA AND PRATO; BIBLIOTECA MEDICEA LAURENZIANA; OPERA MEDICEA LAURENZIANA; FONDAZIONE CASA BUONARROTI.

WHERE AND WHEN

FLORENCE, ITALY, 2003 - IN PROGRESS

AIM OF THE PROJECT

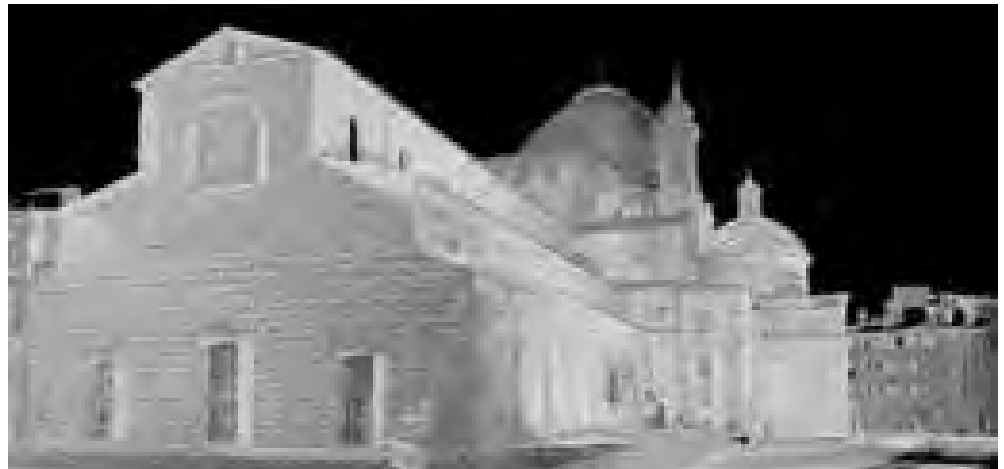
The Michelangelo Project is a research project that uses the documentation, the survey and the 3D modeling of Michelangelo's architectures in Florence to update the documentation, the divulgation and the enhancement of this fundamental heritage. The project, started in 2003 and still in progress, consists in various annual steps regarding the production of survey and the results are being periodically diffused.

INTRODUCTION

Michelangelo projected the Sagrestia Nuova in 1520, on behalf of Clemente VII, Pope belonged to the Medici family. Michelangelo worked on it, as architect and sculptor, for fourteen years, until, in 1534, he went back to Rome. Giorgio Vasari and Bartolomeo Ammannati (1554-1555) concluded it on behalf of Cosimo I. The architectural shell is represented by a cubic space and, above it, there is an hemispheric dome, which evokes, in the inside, the Pantheon. From 1999 and 2006 the Superintendence for Architectural Heritage and Landscape in Florence conducted a restoration campaign, first started by Luciano Marchetti and then ended by Alessandra Marino and

Vincenzo Vaccaro. The intervention interested the restoration of the marble lantern, the control of the wooden cover, the static verification of the dome. Particularly, in the dome, the lesions have been sewed up and the archway plaster have been restored. New products and techniques have been used in this restoration work, under Mauro Matteini's control (part of the ICVBC-CNR of Florence). During the works, many surveys were taken, directly and with laser scanner technology, for The Michelangelo's project. This was possible thanks to a national administration convinced that every intervention on the monumental heritage can be an indispensable occasion to enhance the knowledge.

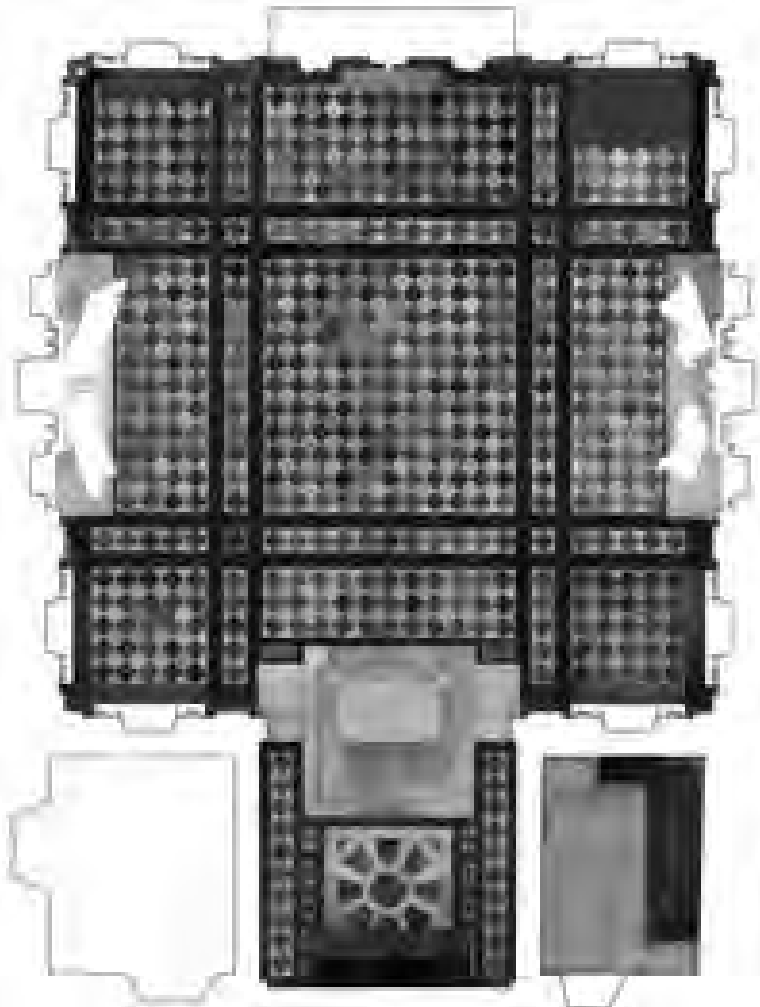
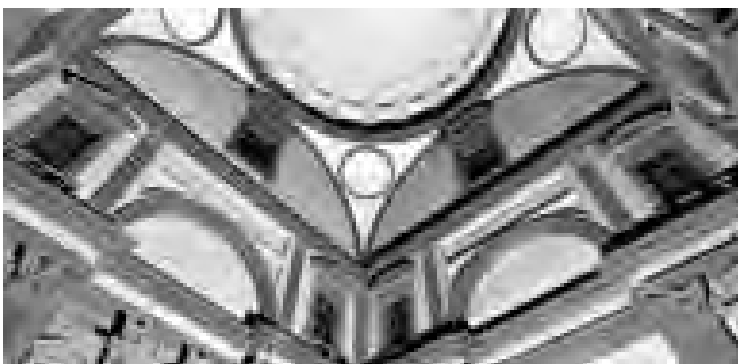
(V. V.)





Laser Scanner survey:
On the left side the section
of the Sagrestia Nuova
point cloud. Below a bidi-
mensional composition of
orthoimage plan.

The study done over the Laurentian complex for the Michelangelo Project used high-tech surveys, in order to have knowledge of the measures, of the geometry and of the matter of the artifacts. This kind of knowledge helps us to preserve and valorize this exceptional historical and artistic heritage. The Department of Architectural Design of the University of Florence and the Department of Architecture of Ferrara of the University of Ferrara, in 2003, started some 3D survey campaigns on the monumental furniture, buildings and on their urban context. The research produced a data bank that comprehend the surveys taken by the staff of both the research structures in 3 years of work. This heritage of documents represents an important source of information for entities, institutions and other, both private and public. The first product of the project is constituted by the Michelangelo's Box, a multimedia installation, which includes the principal contents of the work, first exposed in the Restoration Fair of Ferrara in 2012.





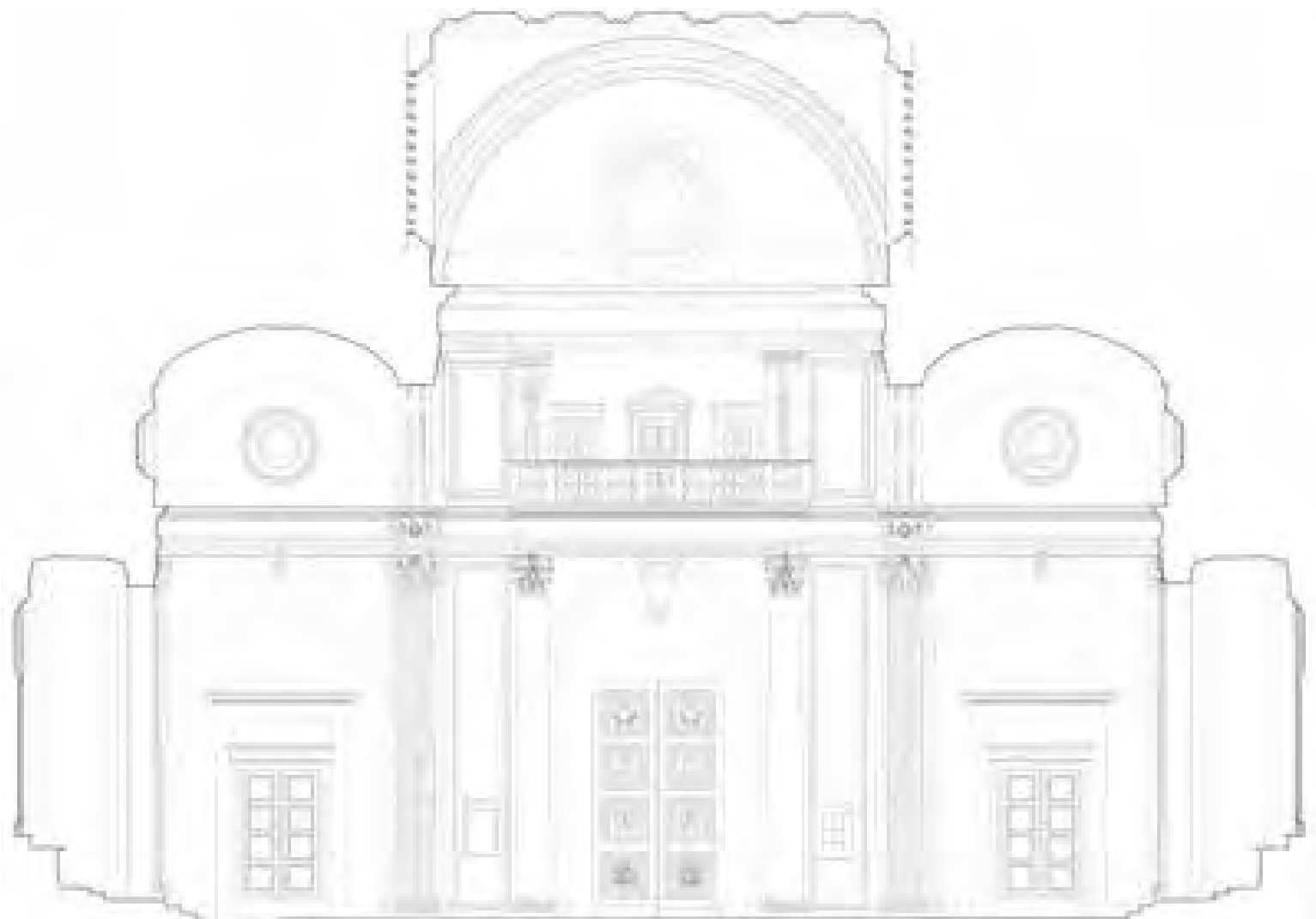
The photomosaic section of Sagrestia Nuova. The base is the laser scanner survey, with which it has been possible to compose the mosaic of photographs of the whole first level, including the statues complex. The second level was made with the interpretation of the shots took from the ground level.

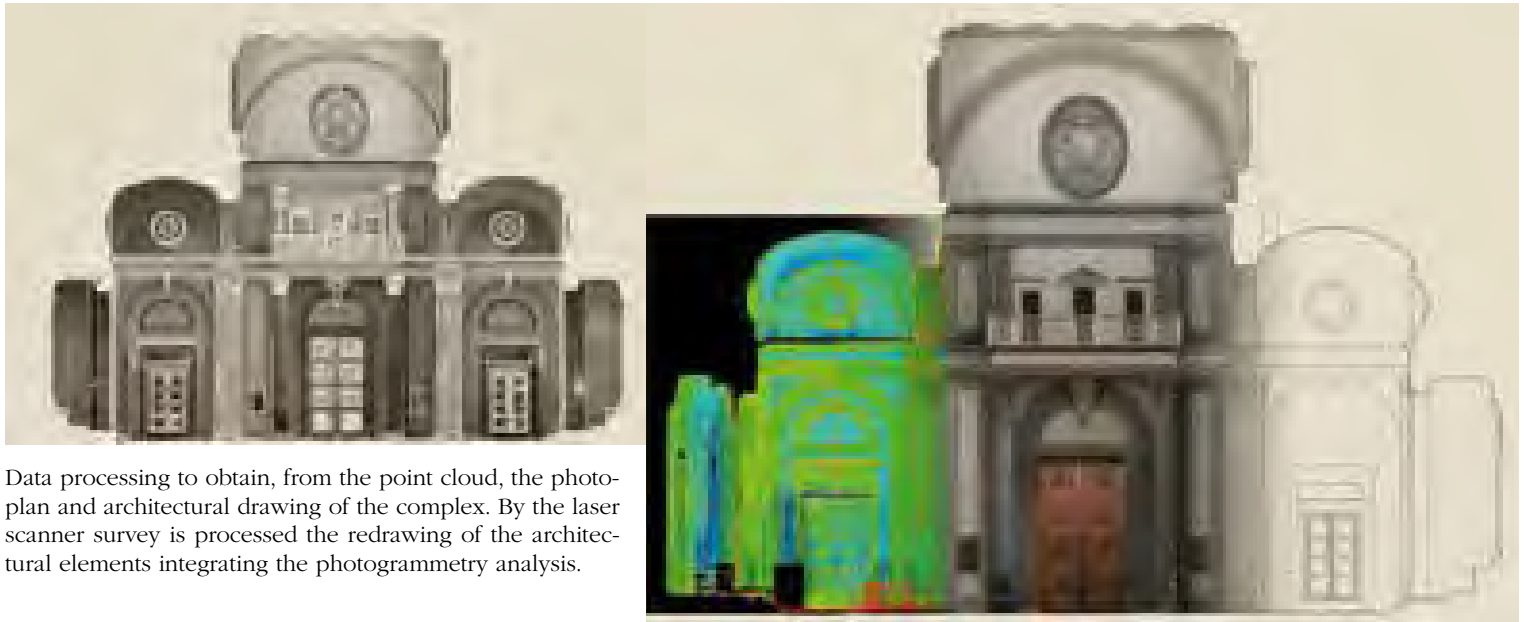


The survey of the Main front of San Lorenzo Church. Laser scanner data acquisition from the inner side and from the outside. These data were integrated with direct survey of the elements, from the ground level till the terrace.



The possibility to take pictures from a higher level improves the quality of the final drawings. Below and next page orthoimage and 2D Cad drawing of the inner front.





Data processing to obtain, from the point cloud, the photo-plan and architectural drawing of the complex. By the laser scanner survey is processed the redrawing of the architectural elements integrating the photogrammetry analysis.



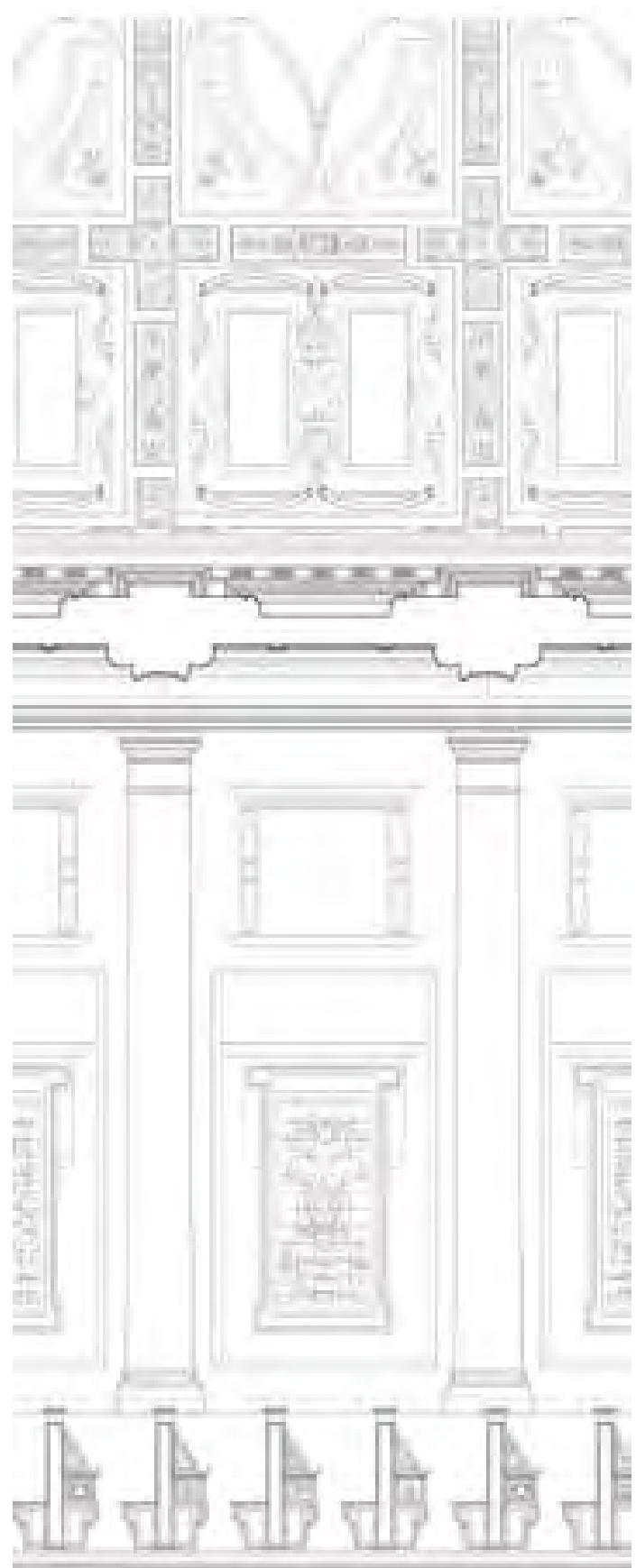
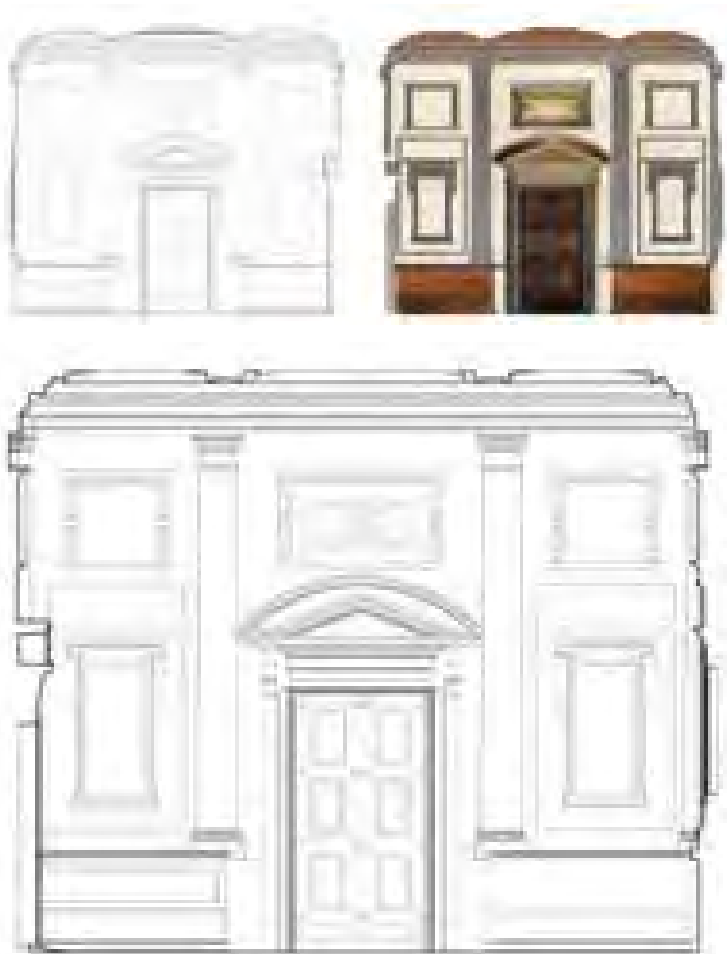


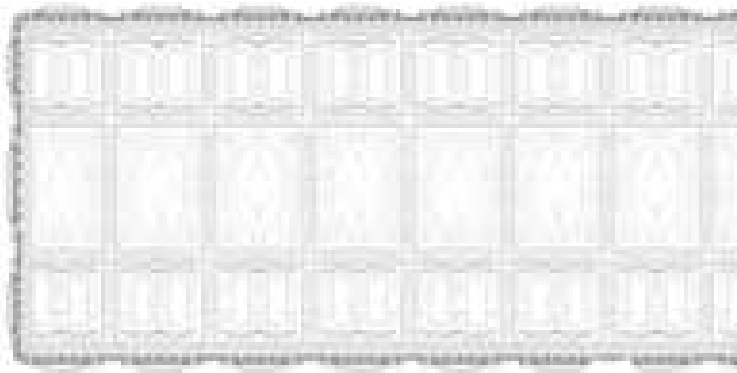
Laser scanner survey of the atrium of the library. On the right a point cloud view and the bidimensional materic front of the atrium.



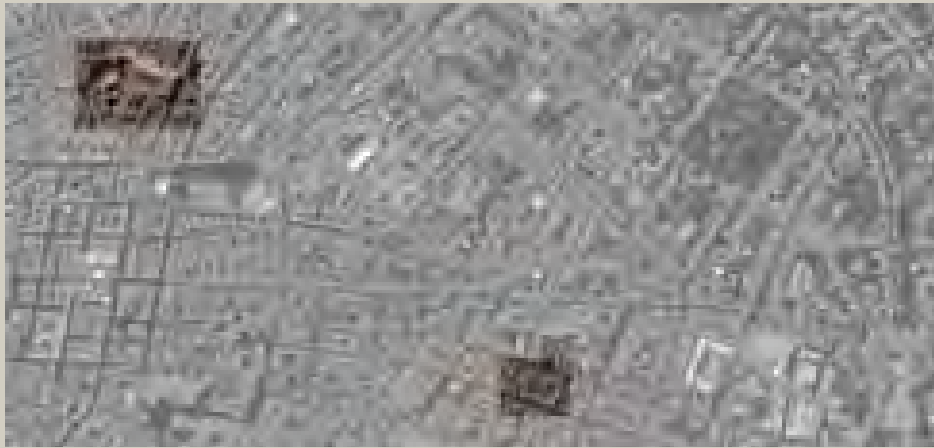
In September 2004, the Laurentian Medici Library commissioned the two departments of the *Research Convention for experimentation and implementation of procedures and survey methodologies for the knowledge, dissemination and valorization of the architecture of the Laurentian Medici Library in Florence and of the Michelangelo's wooden Plutei*. In 2004, for the restoration works of the Plutei of the Library, the Laurentian Medici Library started procedures of documenting the monumental furniture. These documents had the purpose to give the optimal knowledge in order to preserve and valorize this exception historical and artistic heritage.

The two departments worked on the 3D survey of four of the Plutei, located in the monumental context of the Library. This survey will allow to be consulted, in the future, for many different needs, such as metric and geometric valuation and conservation. The research has developed a data bank including the surveys done by the staff of the two research structures on September 2004 and their further elaborations, needed for the complete description of the Plutei, visualized in their real setting, the Library.





Methodology of data acquisition for the outside front of San Lorenzo Church.



The unrealized Michelangelo's project of San Lorenzo main front is a wooden model is exposed to the Casa Buonarroti museum in Florence.



With the integration of a topographic survey and a *shape from motion* survey has been possible obtain a reliable and accurate 3D textured model.

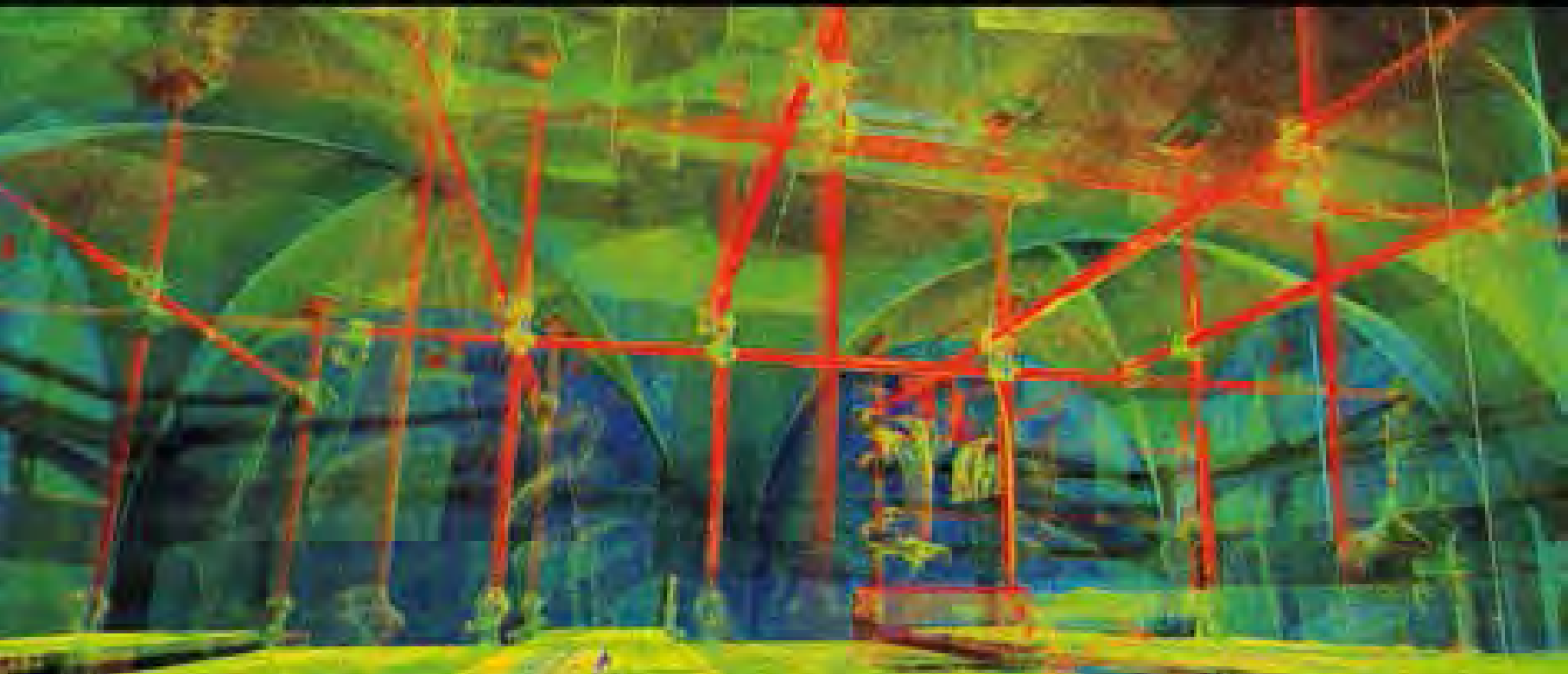


Above: Data acquisition with total station and with camera. The postproduction of the model provided to optimize the mesh, cover the gaps and make available the final output with the integration of the point cloud model of the church.

Between November and December of 1515 Leo X, a member of the Medici family, pope for two years, decided to return to formal visit to Florence, and at that time the idea was born to hold a competition to equip the facade of San Lorenzo, the 'unfinished basilica Brunelleschi patronized by the Medici from the foundation, and place appointed for their burials. Michelangelo obtained, at the end of 1516, from Leo X commissioned for the architectural design of the facade.

Michelangelo made some drawings and a wooden model, which shows how he adjusted the classical proportions of the facade, drawn to scale, after the ideal proportions of the human body, to the greater height of the nave. The work remained unbuilt. Michelangelo did, however, design and build the internal facade, seen from the nave looking back toward the entrances. The large wooden model of the facade, preserved in the museum of the Casa Buonarroti in Florence, was detected both technologies with 3D laser scanner with both technologies photogrammetric SFM.





Experiences of Digital Survey in the Uffizi complex

■ SCIENTIFIC BOARD OF THE PROJECT

SANDRO PARRINELLO

■ TECHNICAL COORDINATOR OF THE PROJECT

SARA PORZILLI

■ PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF PAVIA; UNIVERSITY OF FLORENCE; SUPERINTENDENCE FOR ARCHITECTURAL, LANDSCAPE, HISTORICAL, ARTISTIC ANTHROPOLOGICAL HERITAGE FOR THE PROVINCES OF FLORENCE, PISTOIA AND PRATO, SPECIAL SUPERINTENDENCE FOR THE HISTORICAL, ARTISTIC AND ETHNO-ANTHROPOLOGICAL AND THE MUSEUMS OF THE CITY 'OF FLORENCE; CCC CONSORZIO COOPERATIVE, COSTRUZIONI, IMPRESE ESECUTRICI CMSA SOC. COOP., CEFLA SOC. COOP., CELLINI GTC SOC. COOP.

■ WHERE AND WHEN

FLORENCE, ITALY, 2010 - IN PROGRESS

■ AIM OF THE PROJECT

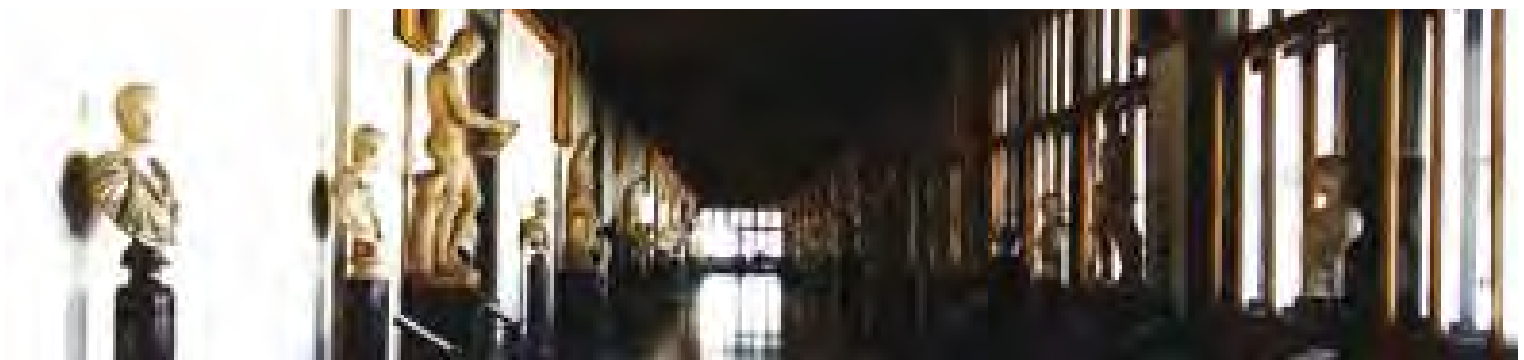
The research activities related to the study of systems analysis for the evaluation of the structural instability of the building works. Through the laser scanner survey are processed models for the study and understanding of the plastic deformation of horizontal structures and vaulted ceiling of the rooms involved in the process of restoration of the Uffizi museum.

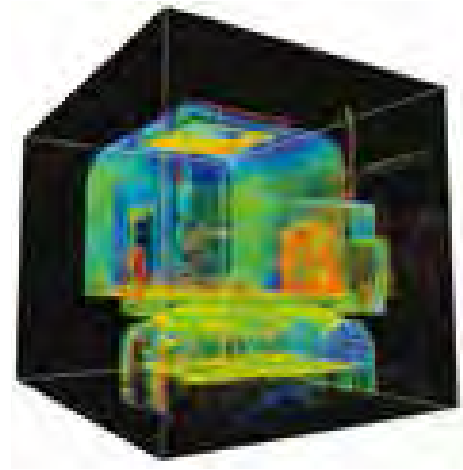
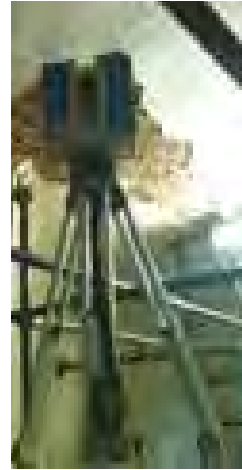
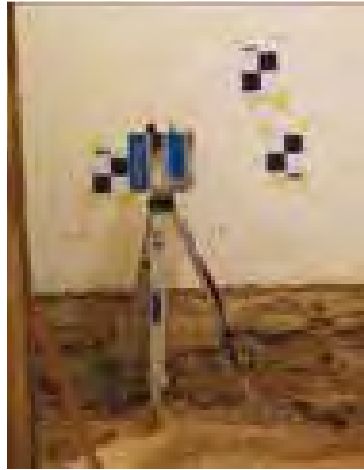
INTRODUCTION

The Uffizi Gallery in Florence represents one of the main historical heritage in Italy, not only for the importance of the artistic operas collected inside but also for the great building itself. Both the palace and the pictorial and sculptural heritage located inside with also the “Historical Centre of Florence” define an extraordinary monumental complex, included into the UNESCO World Heritage Sites. The architectonical project was designed and realized by Giorgio Vasari in 1560, behalf the request of the young Cosimo I, with the purpose to accommodate the offices of the highest magistrates of the State. For this reason, the name of the building is “uffizi”. The building is located in between the Old Palace and the Arno River and from there it is connected to the residence of the Medici in Pitti Palace through the Vasari Corridor. Vasari designed a large building with a U-shaped plan divided into modules, each of them corresponding to an office, which are

repeated along the two wings, characterized by different lengths, from the ancient church of San Pier Scheraggio, incorporated in the building, until the Loggia dei Lanzi. The research activities carried out for ATI society, that has commissioned the work activities for restoration and adaptation inside the main project for the ‘New Uffizi’, funded by the Ministry of Heritage and Cultural and Tourist Activities, have been intended to perform a 3D laser scanner survey for the morphological analysis of a series of rooms destined to accommodate the new exhibition rooms provided by the project. In order to analyze the solidity of the structures and offer to technical operators the reliable bases on which execute the various detailed diagnostic analysis of these rooms there were carried out new methodologies for data acquisition, processing of 2D updated drawings and processing tri-dimensional structural models that have been used for the verification of the structures and operations of consolidation and restoration.

(M. D. B.)





Three-dimensional images of the point cloud with identification of the insertion of the metallic beam.



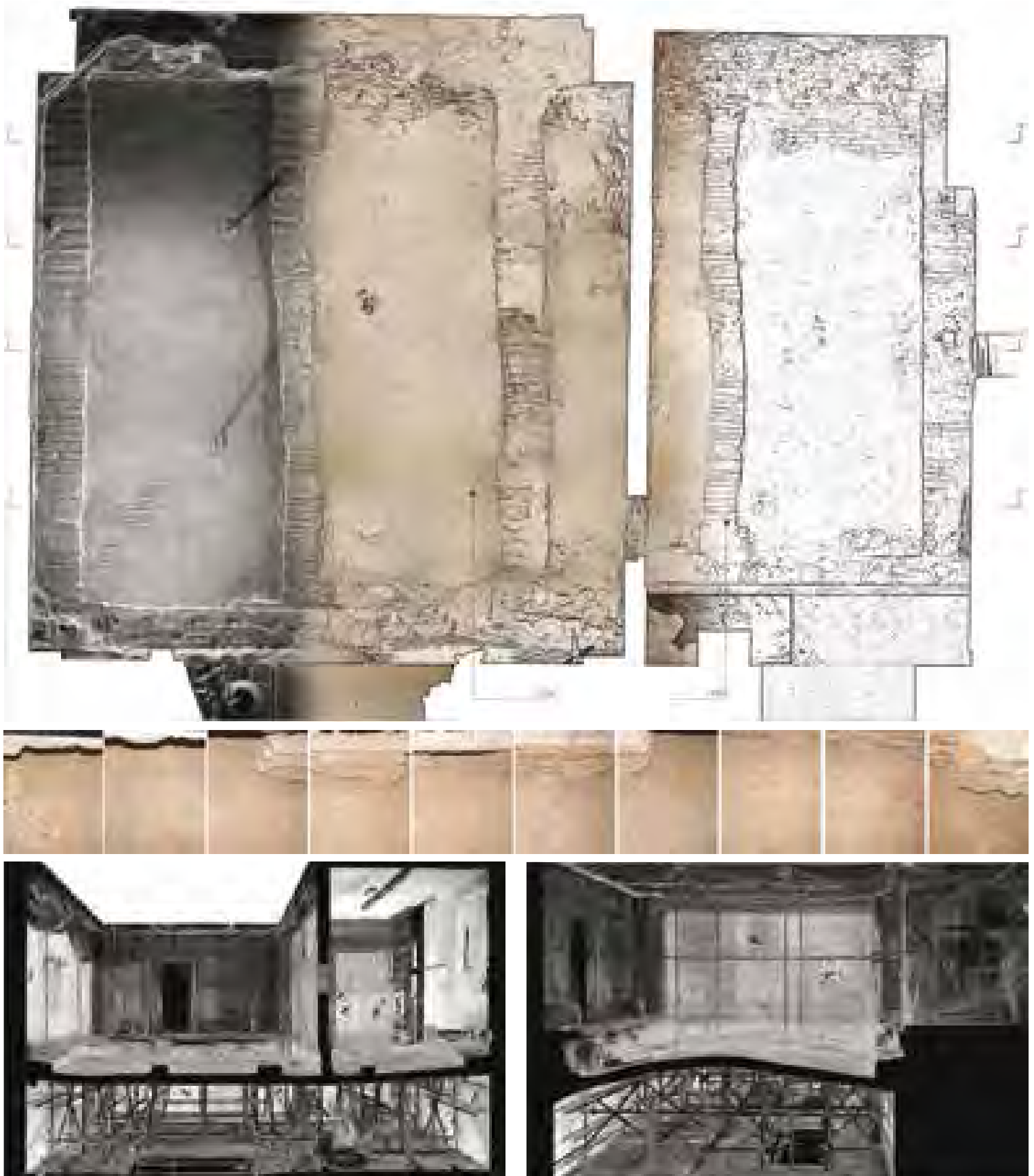
To perform the analysis on the morphological structures of the museum's room, object of study, the research procedure has adopted specific methodologies detecting an high-definition 3D laser scanner, with the development of techniques and scientific procedures, appropriate for the realization of 2D and 3D architectural drawings, planimetric drawings for the analysis of the vertical and horizontal structures, trasversal and longitudinal sections for the study of the possible disruptions.

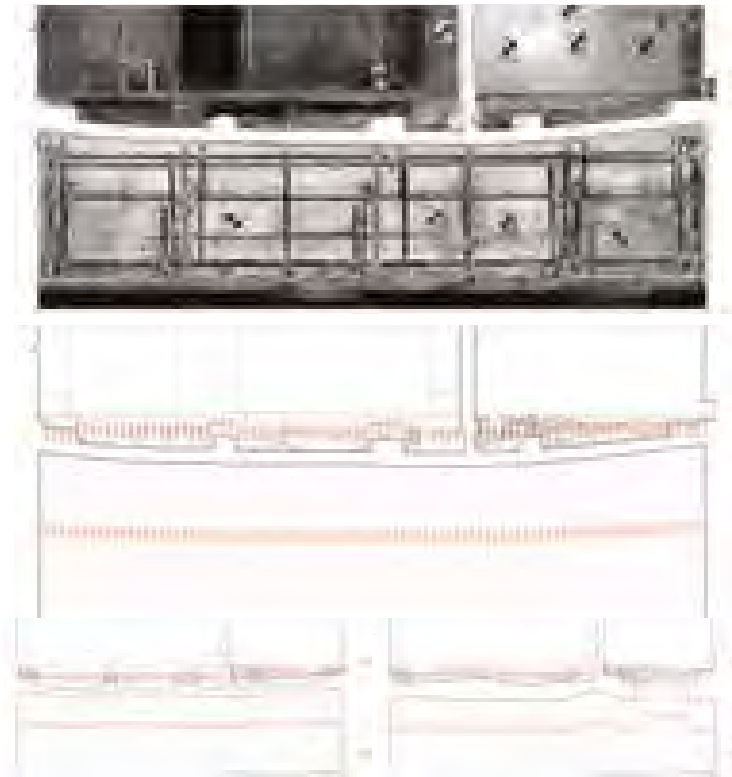
In order to understand in detail the structural behavior of the rooms, more laser scanner survey activities were performed during different time periods (during the first phase of consolidation, during the construction activities and at the end of the work).

The most complex aspect in performing this type of survey has been the need to connect the environments intrados with those of the extrados in order to obtain a cloud of points in which the horizontal structures (floors and ceilings) were totally documented metrically.

Thanks to a survey project well planned and thanks to the possibility to create a sort of topographic metric support it





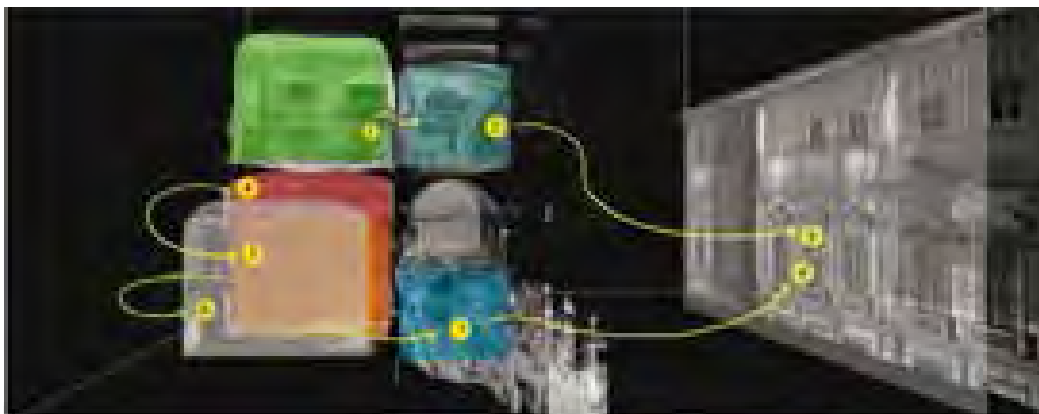


Vertical measurements of the extrados and intrados spaces for the analysis of the morphology of structural garret.

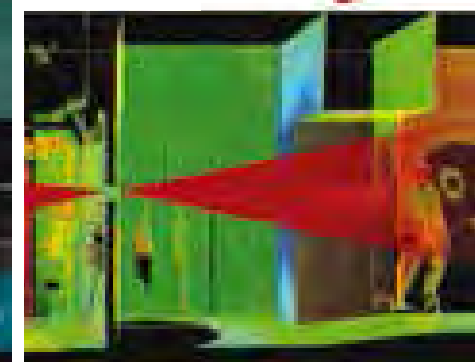
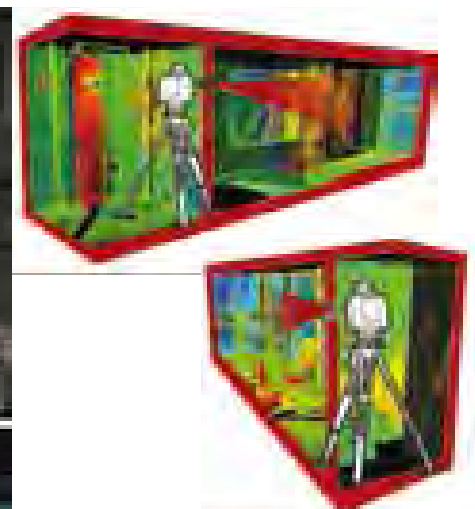
was possible to obtain a point clouds in a high definition and reliability, in which the final level of the result allowed to redesign of constructive and decorative meticulous and allowed to analyze the structures of this architecture.

In the first phase of post-production there have been developed all the 2D vector drawings, namely: in the intrados and extrados plans, vertical sections, cross sections, progressive sections listed every 5-10 cm for metric documentation with very high reliability. After these operations, the development of a 3D model has been carried out from a point cloud for the evaluation of structural deformation in 3 dimensions; the three-dimensional processing was performed through the use of software Rapidform which allowed the definition of calculation models for the evaluation of three-dimensional deformations and deflections that the vaulted have endure during the three phases of survey. In order to have an effective and detailed moni-

In order to connect one space to another one has been sometimes necessary to take advantage of the presence of essays from which to sight the laser scanner. In this way, through the use of targets placed in front of the holes the instrument has been able to successfully execute the registration of the different spaces.



General scheme with the identification of the location and the order in which the laser scans were performed. In order to combine the laser survey of the extrados part with the intrados part it was necessary to scan at two different levels the same portion of the front facade. This was necessary to identify homologous points that led to the union of several scans.

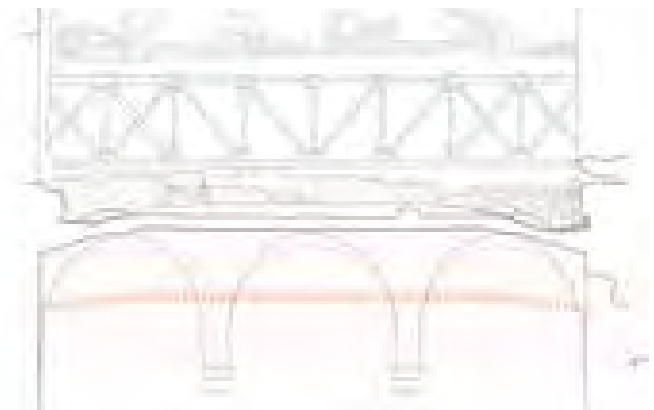


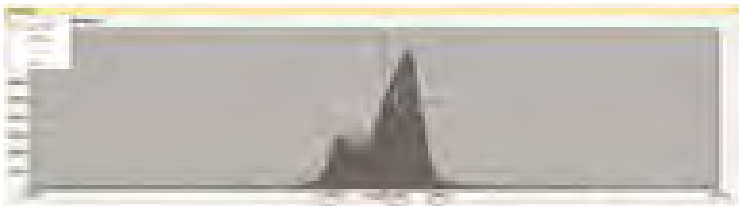
toring it was carried out multiple tasks of recovery and analysis, post production and comparisons between the different processed in accordance with the needs of the site defined by the direction of the work.

For the evaluation of morphological changes in the domes, during and after the interventions of consolidation there have been developed specific three-dimensional models of computation through the use of calculation software.

After scoring the general analysis and detail through the use of the laser scanner survey were in fact carried out some experiments to develop more in-depth evaluations to monitor the vaulted themselves. Starting from the three-dimensional model of the point cloud other models have been created in the mesh of point clouds corresponding to the different stages of recovery laser scanner. Thanks to the use and to the support of a same

Architectural sections with graphic restitutions in “wire frame” and orthophoto. In the extrados of the vaulted surface can be read and understand the structural system. Over the centuries, the rooms of the museum have been modified creating partition walls and structural elements that altered the condition of the masonry and horizontal structures. Through this architectural survey is possible to understand the conditions of each specific wall.





reference system (UCS) the different three-dimensional models were superimposed to go to check the presence of possible deviations between the two surfaces. Subsequently, they were processed for the evaluation of the graphs in terms of number of deviations incurred from the time before and after the intervention of consolidation.

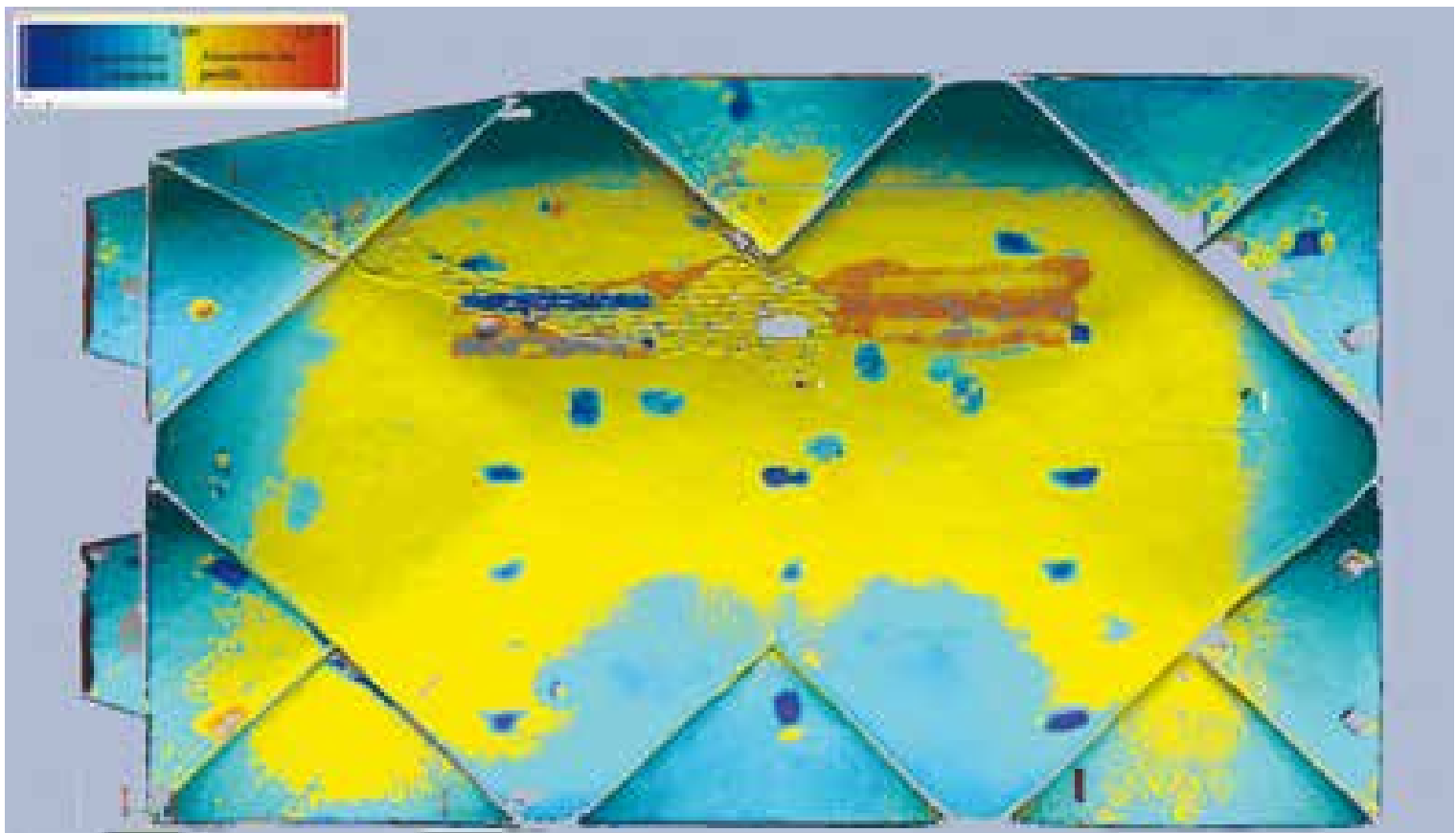
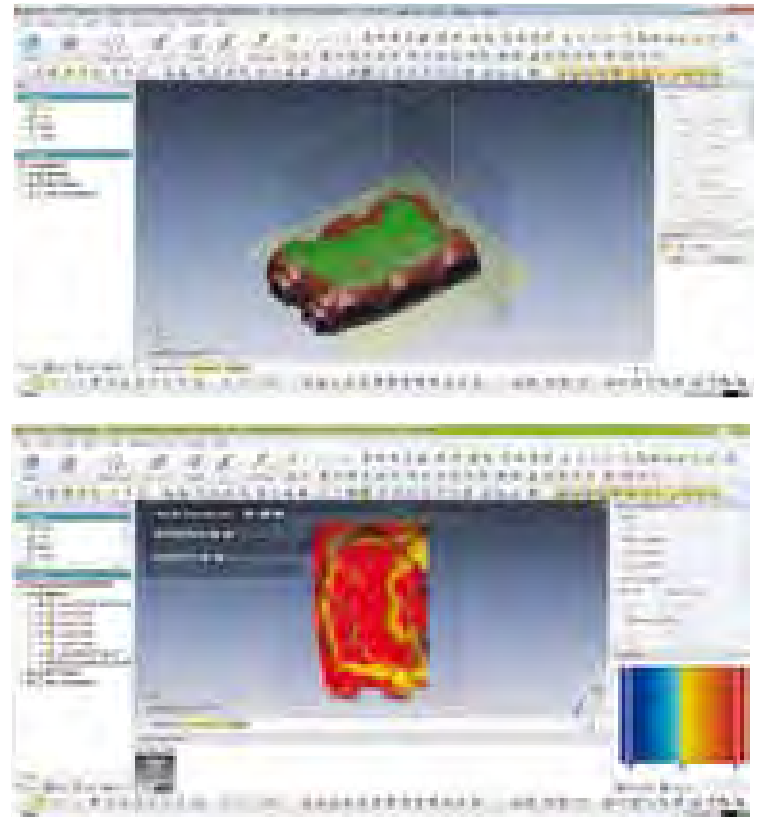
In performing the overlap between the different three-dimensional models can be inserted tolerances reliability of the instrument in order to obtain a result type that includes only the data referring to possible shifts in the real time and not to any errors or omissions own instrument of relief. After entering the tolerance

Intradox model in mesh visualization. To study the morphology of the vault, and the understanding of the possible displacements during the phase of investigation, were carried out three-dimensional mesh models of each stage and then were merged. In this way it has been possible to verify whether during the time the vault underwent dimensional changes in the three dimensions.



parameter, you can query the program to achieve explanatory graphs on the progress of profiles compared (chart Gaussian bell). Through the development of an explanatory chart of the “Bell of Gauss” was also possible to identify what percentage deviations were found between the first and third survey campaign. When the curve is not symmetrical mean that certainly was the case a deviation-deviation of the points made in the analysis. In this case the graph is shifted to the right, it appears that most of the area deflected has undergone a shift in positive (ie height). About 60% of the points has been a rise of between 0.3306 and 2.8481 cm. About 30% lowering of between 0.3306 and -2.1869.

Superposition of three-dimensional models of a surface vaulted into a single vector environment. The models refer to two different surveys carried out at a distance of time to evaluate the displacements of the surface. Thanks to the extreme precision of the laser survey models allow you to read the diversity, even if infinitesimal, of the masonry.





Survey and documentation of Pitti Palace in Florence

SCIENTIFIC BOARD OF THE PROJECT

STEFANO BERTOCCHI, FAUZIA FARNETI, CARLA BALOCCO, GIOVANNI MINUTOLI, GIOVANNI PANCANI

PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE; SOPRINTENDENZA SPECIALE PER IL POLO MUSEALE FIORENTINO; SOPRINTENDENZA PER I BENI ARCHITETTONICI E PER IL PAESAGGIO E PER IL PATRIMONIO STORICO ARTISTICO ED ETNOANTROPOLOGICO PER LE PROVINCE DI FIRENZE, PISTOIA E PRATO.

WHERE AND WHEN

FLORENCE, ITALY, 2005-2011

AIM OF THE PROJECT

The research carried out on Pitti Palace has two main themes: the study of natural ventilation which aim is the possibility to restore the old cooling system of the building and a second topic is dedicated to the analysis of illusionistic paintings whose purpose is to create a semi-automatic system for the production of the digital full scale drawings.

INTRODUCTION

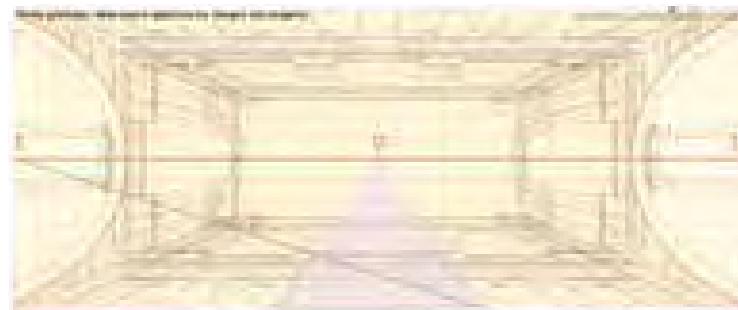
Pitti Palace, the largest of the Florentine palaces, was, during its long history, the palace of three dynasties. It was erected in the second half of the fifteenth century by Luca Pitti, rich Florentine merchant; Giorgio Vasari attributes the project to Brunelleschi, but have not been found so far confirmations documentary. Purchased in 1550 by Cosimo I de' Medici, and Eleonora of Toledo along with the surrounding land is destined to become the beautiful Boboli Gardens, the palace immediately saw a first substantial intervention by Bartolomeo Ammannati, who designed among other things, the grand courtyard; was again expanded between 1620 and 1640, reaching roughly its current size. After the end of the Medici dynasty (1737), Palazzo Pitti passed first to Lorena, who remained there until 1859 (with a brief interlude of Napoleon), and then to the Savoy, becoming from 1865 to 1870 the palace of the new kingdom of Italy and then remained at the disposal

of the royal family until 1919, when it finally came to be part of state assets. From the sixteenth to the nineteenth century have occurred within pictorial and decorative of absolute importance; some of the most important artists of every era have left their mark, creating masterpieces like the painted architecture Mitelli and Colonna, frescoes and stucco work by Pietro da Cortona, the airy background of Sebastiano Ricci for the Grand Prince Ferdinando. A heritage under constant observation by the Ministry and its peripheral organs, which has the task of ensuring the protection and conservation. In this context, the Superintendence for the architectural oversight, since the eighties of the last century, the recovery and restoration of much of the quadrature secentesche that adorn some apartments and mezzanines, welcoming the proposals for new analyzes through advanced technologies, encouraging the implementation and following with great interest the results and understandings.

(L.B.)



Opposite page: Wireframe of the decoration of the Giustizia Hall in Pitti Palace; Above: Orthophotos of a painting of the walls of Museo degli Argenti.



Orthophoto of a ceiling of Museo degli Argenti and descriptive images on the construction of illusionistic painted surfaces based on the explanations made by Andrea Pozzo in his own treatise.

In the past few years a research group was formed in Florence to study the ground floor halls of Pitti Palace that are decorated using architectural illusionism. This pictorial genre amplifies true space through an intelligent application of the theories of perspective, therefore creating illusory structures capable of deceiving the eye “breaking through” walls, raising and/or dilating the ceilings.

The starting point of the research project was the organization of a campaign to assess the monumental spaces of the palace that presented architectural decoration, like the hall that today houses the Museo degli Argenti; here the Bolognese painters, Agostino Mitelli and Angelo Michele Colonna played an important role in the spread of the painting of architecture and figures in Tuscany, their experience was followed as a model by the Florentine artists. They were engaged in decorations for the apartment of Ferdinand II in the Pitti Palace in the first half of the seventeenth century. Their Florentine disciple Jacopo Chiavistelli, more than twenty years later, continued the modernization of the ground floor of the Palazzo Pitti, in 1661, working on the apartment of Cosimo III, in the right wing of the Palace and ten years after, on the Vittoria della Rovere’s complex.

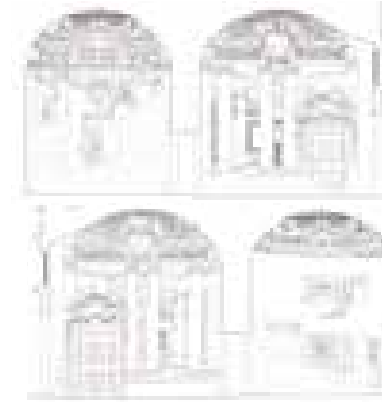
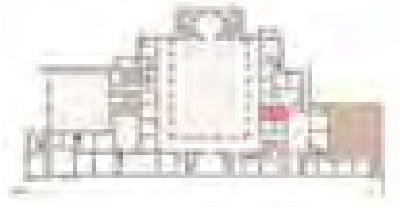
The two apartments are both constituted by a succession of rectangular rooms in enfilade. The painted decorations start from the base of the walls and end at the center of the vault with the so-called “sfondato” in which are usually represented the figures of divinities who are dedicated rooms. The desired effect is, therefore, created by using anamorphic projections which, on such surfaces, appear complex and hard to understand without the help, on the one hand, of the treatise writings on the subject from that era, and, on the other, of corrective instruments for the dimensional control of the representations portrayed.

The survey has allowed us to create an extremely reliable orthophoto of the decorate surfaces in the monumental rooms within the Pitti Palace on the ground floor, and the creation of orthogonal projections of the surface of decorated vaults. From the orthophotos we were able to obtain graphics with the reproduction of drawings of the actual frames that make up a sort of primary metric cartography for further research. The studies on the anamorphosis and the diagnosis of the state of conservation and the exact evaluation of the restoration works is possible only if the analysis is performed on drawings that reproduce in full size all the parts of the object under study, without any foreshortened portion. In order to represent a curved surface in true size, is necessary to realize its “unrolling”, that in the representation on a plane of the pairs of curvilinear abscissa and the lines of impost.

The majority of traditional survey techniques are conceived to simplify as much as possible the measurement and rep-



The laser scanner survey makes possible acquire a great number of texturized points and it's one of the most useful technique for the survey of painted decorations.



The preliminary operations to perform the unrolling include creating digital drawings in wireframe and a three-dimensional model of the vault.

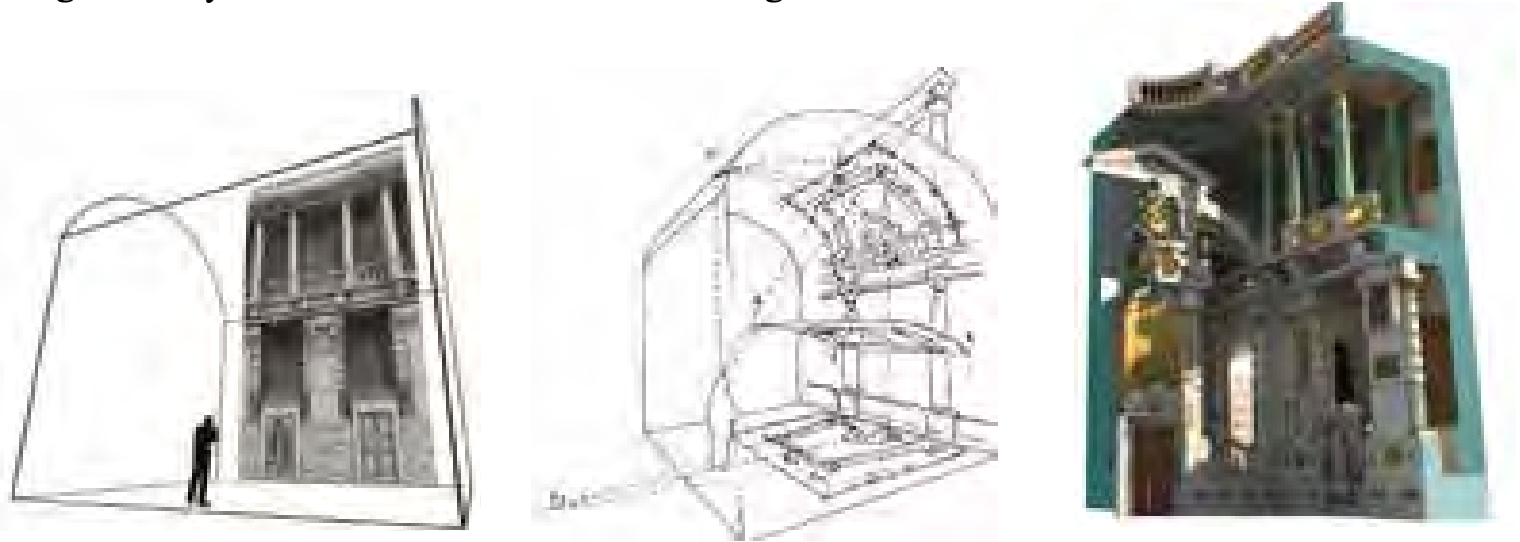


Decoration of an hall of Cosimo III and Margherita Luisa d'Orléans's quarter.



The curves of the wireframe of the paintings can be projected onto the virtual model of the ceiling and then the unrolling of the surface and of the drawings can be made.

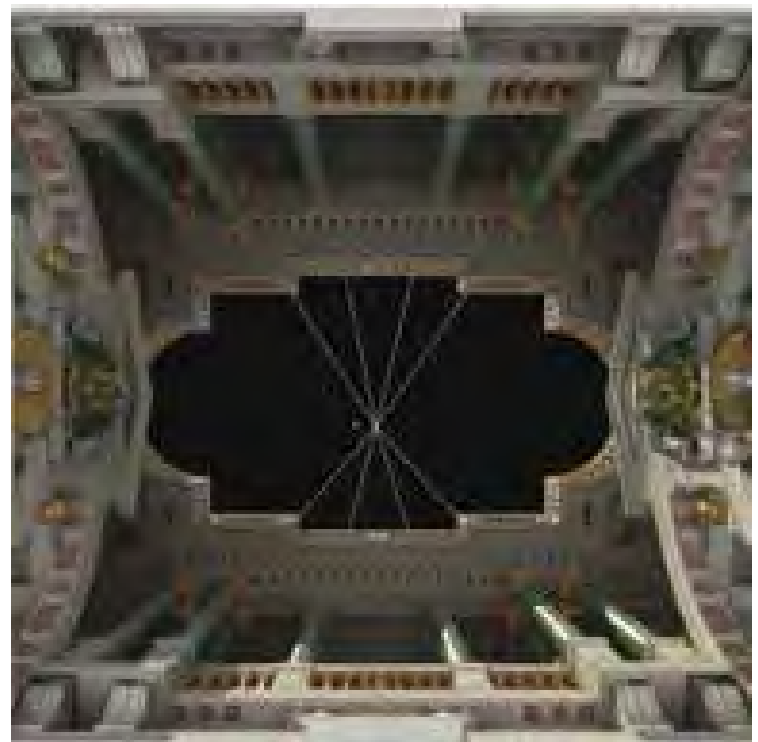




The study of seventeenth and eighteenth century treaties about the perspective and the decoration of vaults and ceilings made possible to make some assumptions about how the prospective system of quadrature was designed with anamorphic distortion on curved surfaces. The rules of geometry made it possible to rebuild the three-dimensional models representing the painted architecture elements present in the Museo degli Argenti.



Virtual view of the 3d model of the painted architecture represented in the Museo degli Argenti. The room features a painted double-columned loggia that ends with a balustrade over which there is a “sfondato”.



resentation of the object, through the discretization, but for this reason are limited in the description of complex curved surfaces. With the introduction of the laser scanner, it was possible to decrease the possibility of discretization and error because the millions of acquired points provide color data. In addition, the dense point cloud allows to extrapolate three-dimensional models composed by triangular mesh or consisting of NURBS. On this kind of surface it is possible to project, by a CAD software, the traced vectors derived from orthographic views of the point cloud or from orthophotos previously made and calibrated on the cloud. Then

is possible to realize the un-rolling of the surface and of the paintings on it reported, getting the essential elaborate, in true size, for the representation of the results of diagnostic studies and the project of any restoration. The procedure currently more evolved for the unrolling of the surface and the painted decorations on it, in order to obtain the drawing in real size, consists of a series of phases extremely “time consuming”. The future objective of this research project is therefore to accelerate the process of true size representation of the frescoed by semi-automatic techniques based on computer-based tools.

NATURAL VENTILATION

Natural ventilation techniques can provide the energy saving otherwise consumed by heating, cooling and ventilation systems in a building. Reliable information on the existence and working conditions of natural ventilation systems inside historical buildings is a complex task. Wind tunnel testing is a fundamental tool for natural ventilation systems investigation, in particular when it concerns historical buildings. Wind tunnel testing is also important for providing CFD boundary conditions and for representing and analysing the full unsteady aerodynamic interaction of the atmospheric boundary layer with building. In the present paper wind tunnel tests, carried out both by wind and buoyancy effects with unsteady conditions, inside a scaled model of a historical building (the Pitti Palace





in Florence), were performed to investigate the internal air flow induced by the present natural ventilation system. The research has been carried out jointly by the Energy Engineering Department of the University of Florence and CRIACIV (Inter-University Research Centre on Wind Engineering and Building Aerodynamics). During a survey inside the Pitti Palace some ducts covered by grids in the floor between the ground level and the basement were noticed; in particular in the left side of the building in which are collocated the so called “summer rooms”. These ducts let air free to circulate between the two floors. This behaviour could be due to the mechanical action of the wind coming from the back side of the building. Moreover in the basement were found some channels in which the water coming from the iceboxes went through. This surely contributed to cool the ambient in the basement floor. A re-

In the first testing set-up the model was positioned inside the wind tunnel where an incoming low turbulence ($<1\%$) flow was generated. Through PIV techniques the flow inside some rooms was measured in different configurations (opening and closing the first floor windows at the back side). The flow in the back yard was investigated to know the condition at the inlet zone. In the second run of tests the garden was covered by a layer of dry ice in absence of forced wind; like the previous case, the flow inside the rooms and in the back yard was investigated.

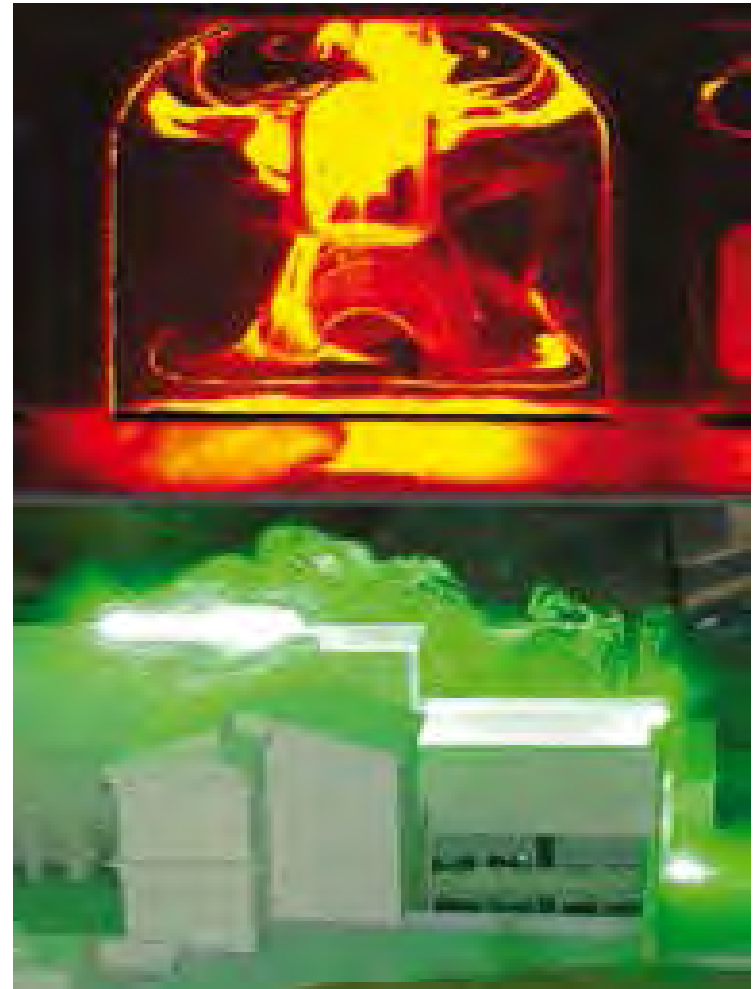
The global size of the model then resulted in 1.5 x 2.0 m, including the garden and the front square with surrounding buildings; these last and the part of the Palace not directly studied, were made of cork and plywood. All the doors and windows were constructed to be opened or closed. The single part of the palace that concerns the left summer apartments were made of transparent plastic and polycarbonate material so that flow visualization and PIV (Particle Image Velocimetry) measurements can be done using smoke tracer.



search program then started aimed to investigate the internal behaviour of the air fluxes distribution in order to verify the functioning conditions and the efficiency if of the existing a natural ventilation system was possible in those spaces. The physical model used for tests was built at the Institute of Art of Florence (ISA); a 1:200 scale was chosen, suitable both for the dimensions of the wind tunnel and for maintaining the blockage effects as limited as possible. The purpose of this study is to verify if an internal air velocity flux develops from the rooms of the basement to those at the ground level. The flow can be generated by the wind present in the garden entering through the windows at the back or by the temperature differences due to the adiabatic saturation process of the external air that flows down the Boboli Garden. Obtained results confirm that an air flux of air is generated coming from the Boboli Garden, entering in the basement rooms and then streaming towards the ground level rooms through the ducts in the floor. The physical phenomenon involved in the process needs to be further investigated, especially from a quantitative point of view. The pressure and temperature distribution in the internal and external side of the facades should be measured in order to know the pressure gradient moving the flux; the temperature in the back (inlet) and in the frontal (outlet) windows should be investigated as well. Finally other velocity measurements can offer a better knowledge referring to the continuity equation.

(G. M.)

The ventilation of the internal space was evaluated in two different settings for the following conditions: — presence of an incoming wind from the backside of the building; absence of forced wind, simulation of the buoyancy effect by positioning dry ice (CO_2 ice) on the Giardino di Boboli behind the building.



The analysis inside the wind tunnel, using tracers, will allow the simulation of air flows dynamic effects through the rooms of building, taking into account shape and roughness of different surfaces and the urban morphology around the palace.





The survey of the Morro San Pedro de la Roca of Santiago de Cuba



SCIENTIFIC BOARD OF THE PROJECT

SANDRO PARRINELLO

PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE; UNIVERSITY OF PAVIA; UNIVERSIDAD DE ORIENTE DE SANTIAGO DE CUBA; OFICINA DEL CONSERVADOR DE LA CIUDAD DE SANTIAGO; MUSEUM OF MORRO SAN PEDRO DE LA ROCA.

WHERE AND WHEN

SANTIAGO DE CUBA, CUBA, 2005-2006

AIM OF THE PROJECT

The architectural survey of the Morro fortress in Santiago de Cuba was the first case study of project for the documentation of Antonelli's work. The fortress, an UNESCO heritage site, is situated at the entrance of the bay of Santiago, overlooking the sea, and constitutes, together with the other defensive structures built for the defence of the coast of the East Cuban, an important case study for the analysis of the typical triangular forts. The project took the form of boards of study exposed in the same fortress, which houses a museum.

At sunset, on the Caribbean Sea, a cannon, loaded with blanks, resonates from the Plataforma de la Santísima Trinidad every day. The first of January, 2006, in addition to the anniversary of the revolution, for the National Museum of the Castillo San Pedro de la Roca, Morro de Santiago de Cuba, was the anniversary of the well-known ceremony of “*the puesta del sol*”. On the occasion of this double celebration, it was presented the inauguration of the exhibit “*Forma y color de una fortificación suspendida en el tiempo*” organ-

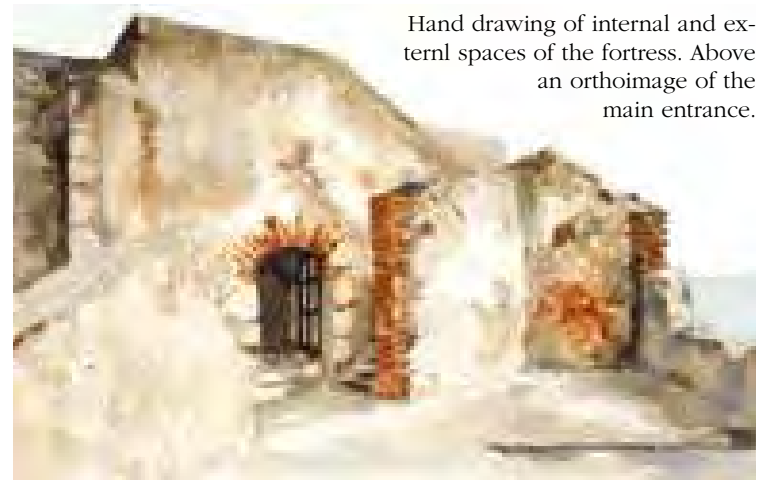
ized by the Department of Architecture of the University of Florence in collaboration with the University of Oriente in Santiago de Cuba and the Oficina del Conservador of the Ciudad de Santiago de Cuba. The fortress, the same object of exposure, had been under investigation for several months by researchers and surveyors who made, on site, a search campaign, invited by the local superintendents to determine reliable drawings for the valorization of the architectural complex and the military systems.





The construction of the fortress of Santiago on top of the hill at the mouth of the bay was completed in 1643 and took the name of the Fortress of San Pedro Roca in honor of the governor of the city. After the assault on Santiago successfully conducted by the British headed by Sir Francis Drake, who penetrated the defenses in 1662 and boarded the fortress, in 1664 the engineer Ciscara Ibanez built the platform for the gunner above sea level. In addition to the platforms Ibanez built the general defense system of the bay, following a very similar type of work done by Antonelli in the bay of Havana,

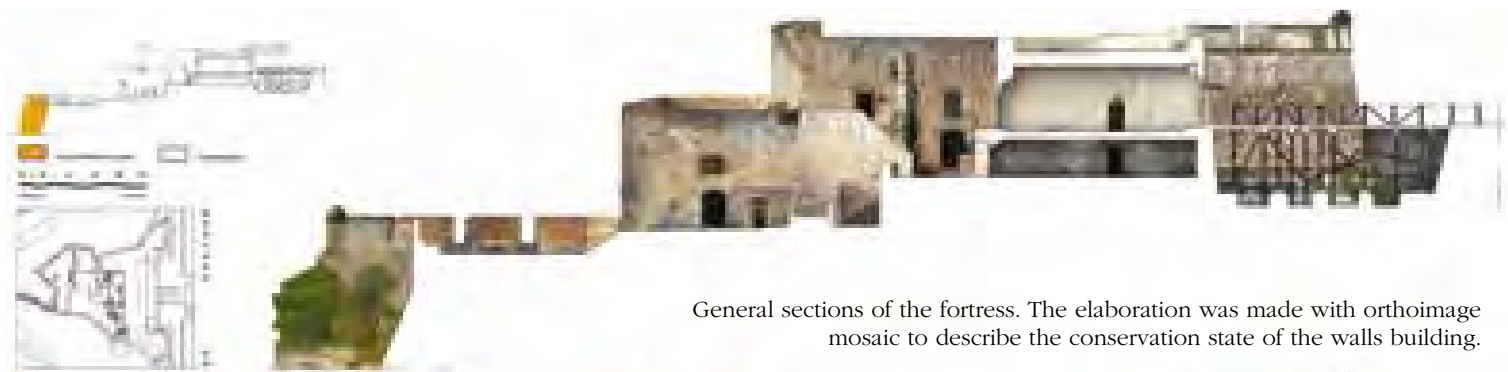
supplemented by other defensive complexes of smaller size, such as the Fortaleza Estreglia, named for its plant Starry, placed in direct line to the control of the entrance to the bay, and other locations on the opposite side to the Morro, the site named Socapa, with the purpose of lining the shot on the side of Morro. The fortress suffered numerous attacks throughout the eighteenth century at the hands of the English; several battles took place just offshore near the Morro and today the seabed in front of the fortress are veritable museum full of submerged ruins of warships of those eras.



Hand drawing of internal and external spaces of the fortress. Above an orthoimage of the main entrance.

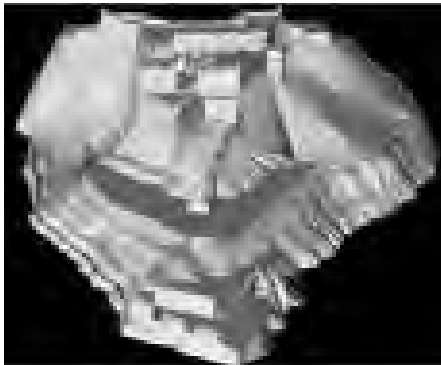
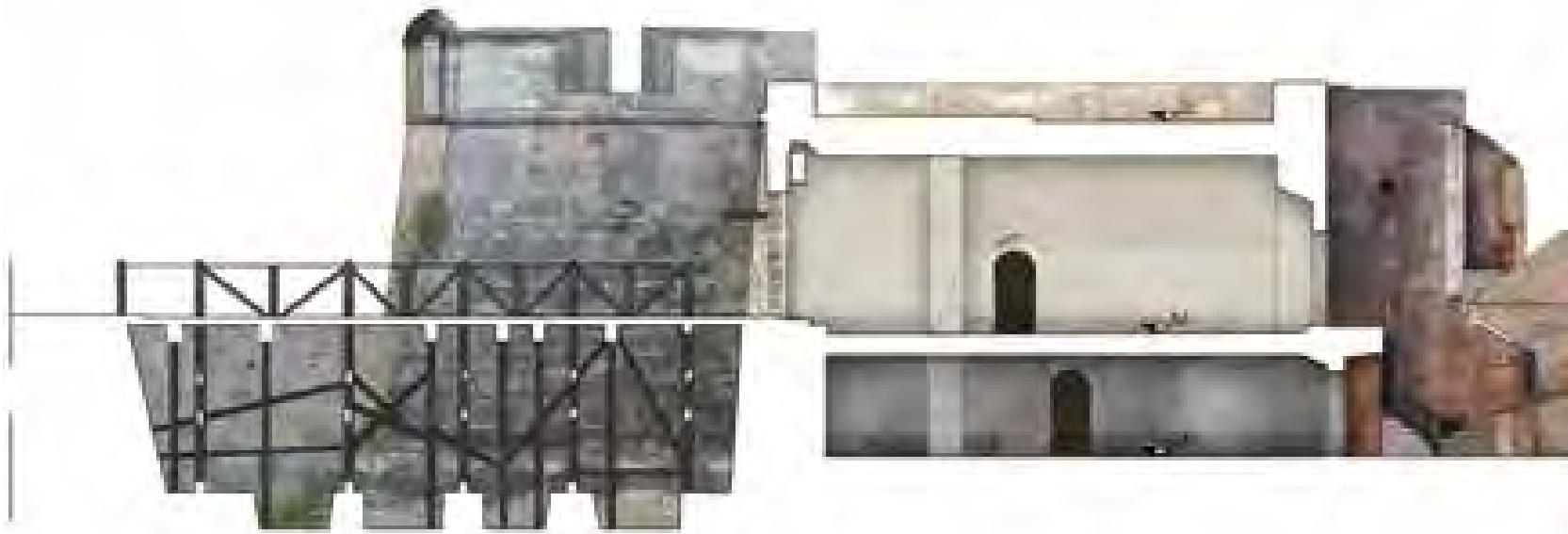


Plans of the fortress. Trilateration system for the direct survey of the main inner spaces.

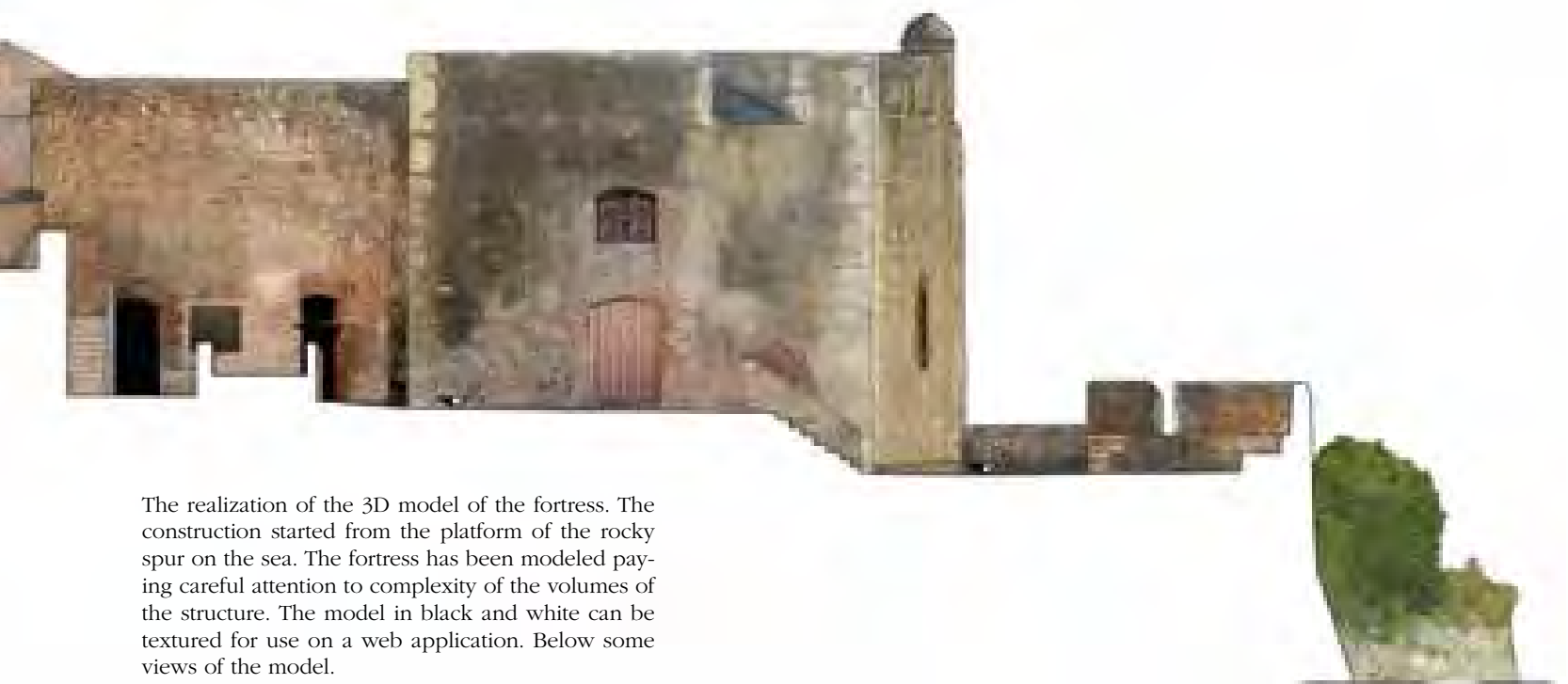


Orange: interpretation parts.
White: orthoimages parts.

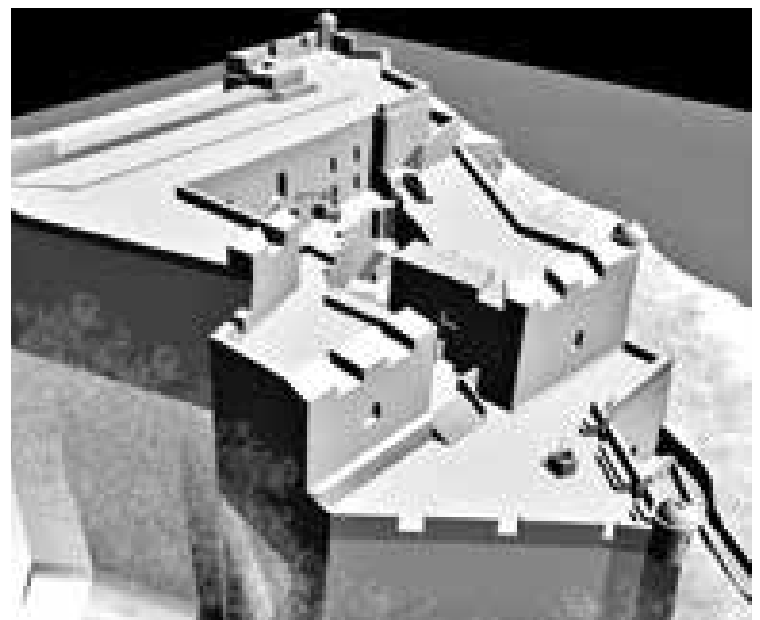




The eighteenth century can be considered the golden century of military fortifications in Cuba. Fortresses were built before they were modernized in accordance with the evolution of military strategy. Never prior to the Spanish crown had devoted so much amount of economic resources for the construction of fortifications. In 1740 the governor of the city of Santiago, Don Francisco Cajigal de la Vega improved defensive coastal places converting them into impregnable fortresses to repel the repeated attacks of the British. In the second half of the nineteenth century, the fortress of Morro was no longer deemed adequate and functional for the times and was transformed into a prison. Later abandoned, in 1962, was restored and, at the end of the works, addressed to the museum which was inaugurated on July 23, 1978. On the proposal of the provincial commission of the monuments of Santiago de Cuba, the castle was declared a national monument in 1979 and today “el castillo de san Pedro Roca, Morro



The realization of the 3D model of the fortress. The construction started from the platform of the rocky spur on the sea. The fortress has been modeled paying careful attention to complexity of the volumes of the structure. The model in black and white can be textured for use on a web application. Below some views of the model.



de Santiago de Cuba”, declared patrimony of humanity from 4 December 1997 together with the complex system of fortifications that are adjacent, as an example of Renaissance military engineering of the Caribbean, is used as a museum and venue for cultural events.



The survey of the fortresses of Havana



SCIENTIFIC BOARD OF THE PROJECT

SANDRO PARRINELLO

PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE; UNIVERSITY OF PAVIA; OFICINA DEL HISTOREADOR DE LA CIUDAD DE LA HAVANA; UNIVERSITY SAN HERONIMO OF HAVANA.

WHERE AND WHEN

LA HAVANA, CUBA, 2007-2009 - IN PROGRESS

AIM OF THE PROJECT

The city of Havana has numerous forts defending the bay and the coast. The system of access to the bay, consisting of the Morro fort and the fort of La Punta, on the opposite side, the fortress of the Real Fuerza, the fortress of Cavanna, and the Casaforte of Chorrera and torreón of Cojmar, with other portions of walls and architectural elements scattered throughout the city, has been the subject of study. The survey had the purpose to obtain plans and sections as well as navigable 3D models. The documentation, in this case, was focused to provide the material useful to manage the restoration, valorisation and management of the sites.

The interest aroused from the event in Santiago has turned the research towards a study on the fortifications of Havana, entirely projected by the Antonelli family. Within this research in 2008, in 2009 and 2010, students from the University of Florence carried out some surveys for a period of over six months in Cuba, by committing in measurement campaigns coordinated by university professors and researchers on Cuban territory. The historic fortunes of Havana were a product of the exceptional function of its bay as an obligato-

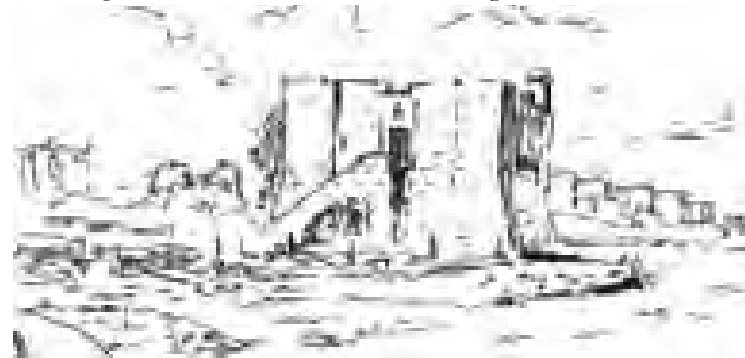
ry stop on the maritime route to the New World, which consequently necessitated its military protection. The extensive network of defensive installations created between the 16th and 19th centuries includes some of the oldest and largest extant stone fortifications in the Americas, among them *La Cabaña* fortress on the east side of the narrow entrance canal to Havana Bay, *Real Fuerza* Castle on the west side, and *Morro* castle and *La Punta* castle guarding the entrance to the canal.



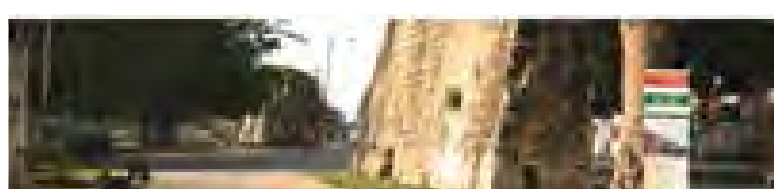
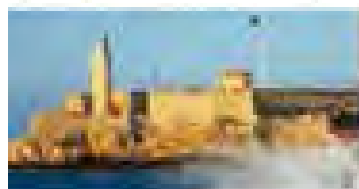


1	FUERZA VIEJA	
2	LA REAL FUERZA	
3	LOS TRES REYS DEL MORRO	
4	SAN SALVADOR DE LA PUNTA	
5	LA CHORRERA	
6	COJIMAR	
7	TORRIONE DI SAN LAZARO	
8	LA MURALLA	
9	LA CABANA	
10	IL PRINCIPE	
11	ATARES	
12	HORNABEQUE DI SAN DIEGO	
13	BATTERIE	

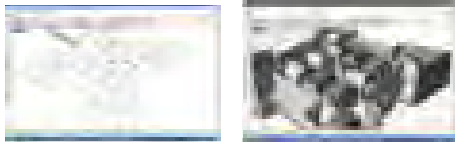
The complex system of fortifications that protected Havana, its port and its dockyard is comprised of the *Fortaleza de San Carlos de la Cabaña* –one of the largest colonial fortresses in the Americas– on the east side of the narrow entrance canal to Havana Bay; *Castillo de la Real Fuerza* –one of the oldest colonial fortresses in the Americas (begun in 1558)– on the west side of the canal; and *Castillo de San Salvador de la Punta* and *Castillo de los Tres Reyes del Morro* guarding the entrance to the canal; as well as the *Torreón de San Lázaro*, *Castillo de Santa Dorotea de Luna de la Chorrera*, *Reducto de Cojimar*, *Baluarto del Ángel*, *Lienzo de la Muralla y Puerta de la Tenaza*, *Restos de Lienzo de la Muralla*, *Garita de la Maestranza*, *Cuerpo de Guardia de la Puerta Nueva*, *Restos del Baluarte de Paula*, *Polvorín de San Antonio*, *Hornabeque de San Diego*, *Castillo de Santo Domingo de Atarés*, *Castillo del Príncipe*.



The first city founded San Cristobal de la Habana, where the port collected annually rich merchandise, soon it was in the center of the rise of a system of forts aimed at the security of its core.



The 3D model construction of the Real Fuerza fortress. From the survey to the 2D drawing till development of 3D surfaces.



Details of the main elements of the fortress. The modeling has focused on the surface of the structural elements of the inside and outside of the structure.



The works of the Antonellis, Italian engineers from Gatteo, who in the sixteenth century organized the defence strategy of the European colonies in Central America, can be considered a cultural link between the Italian Renaissance tradition and the expressions of colonial architecture, in the historic period widely spread in the overseas territories. Significant example of the expression of Italian and Spanish culture in Central America, nowadays the fortresses built by the Antonellis are world-wide considered to be important cultural monuments, protected by UNESCO as a World Heritage Site, and representing the symbol of the region they are built in. The project carried out by the Antonellis consisted in organizing a territorial defensive system, a network of fortresses and ramparts in defence of the Spanish territories. These works have never been studied before in their complexity because of socio-political events that involved the countries where they are located. That is the reason why today there isn't any complete and updated database informing us about their state of preservation, and also the problems that may concern such context, besides the projects and the planning activity of the mentioned Italian engineers.



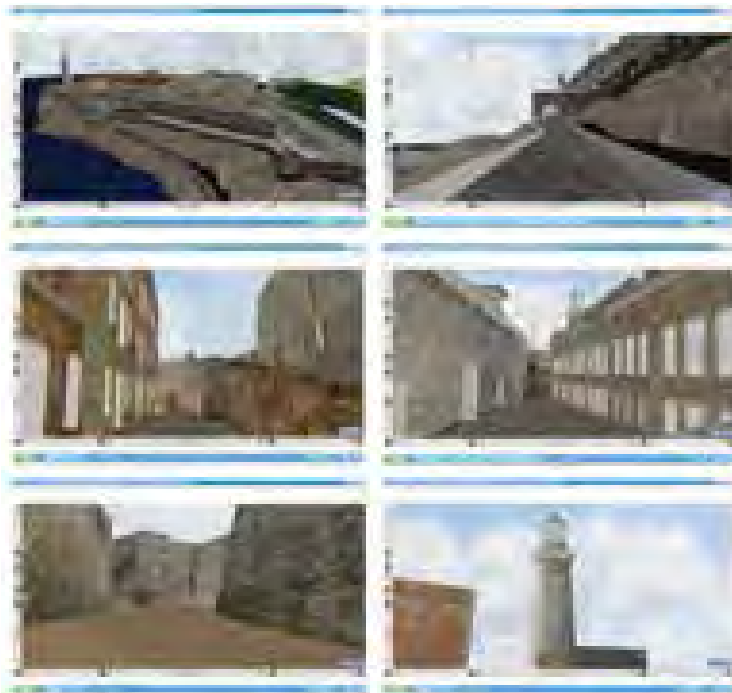


Plan and sections of the Tres Reyes del Morro Castle. The building was built on a rocky spur, and the conformation of the structure makes it difficult the direct survey and camera shooting.

The main objective of this survey was not only to produce reliable drawings of the fort - e. g. high-definition plans and sections with qualitative information - but also to structure a multimedia project that could be explored through interactive platforms, a drawing showing the complexity of the environment, able to enhance the fortress and to highlight the relationships it has with the surrounding context. The survey of the fortresses up to now studied, determines an important database, where measurements are three-dimensional, and where the construction of the three-dimensional image of the fortress is the result of a process of critical interpretation on the database, adding information to the system. The research has an additional importance due to its character of database for the memory of the present state of the building, but also useful to test in a virtual way any solution for the restoration or planning actions peculiar to each fortress. The virtual design can also allow the development for the enhancement of systems to enjoy these sites, not always easily visitable, relating the complex spatial connections among the works of the Antonellis.

The accuracy and the high number of the pictures acquired allow to get a high resolution of the orthoimage section.





Views of the textured model from the web navigation structure *Cortona 3D*. In this case has been simulated the presence of the visitors inside the 3D model and the environment in which it is located.

Above: the quality and the accuracy of the 3D model elements in black and white and with the texture of the orthoimages.



lighthouse

Tajeda rampart

Bunker artillery

Horne structure

Austria Rampart

East Ramp

Casemates

San Juan Baustista Chapel

West Ramp

Carmen Battery

Bridge

Mercado bastion

Polvorin

Triangular staircase

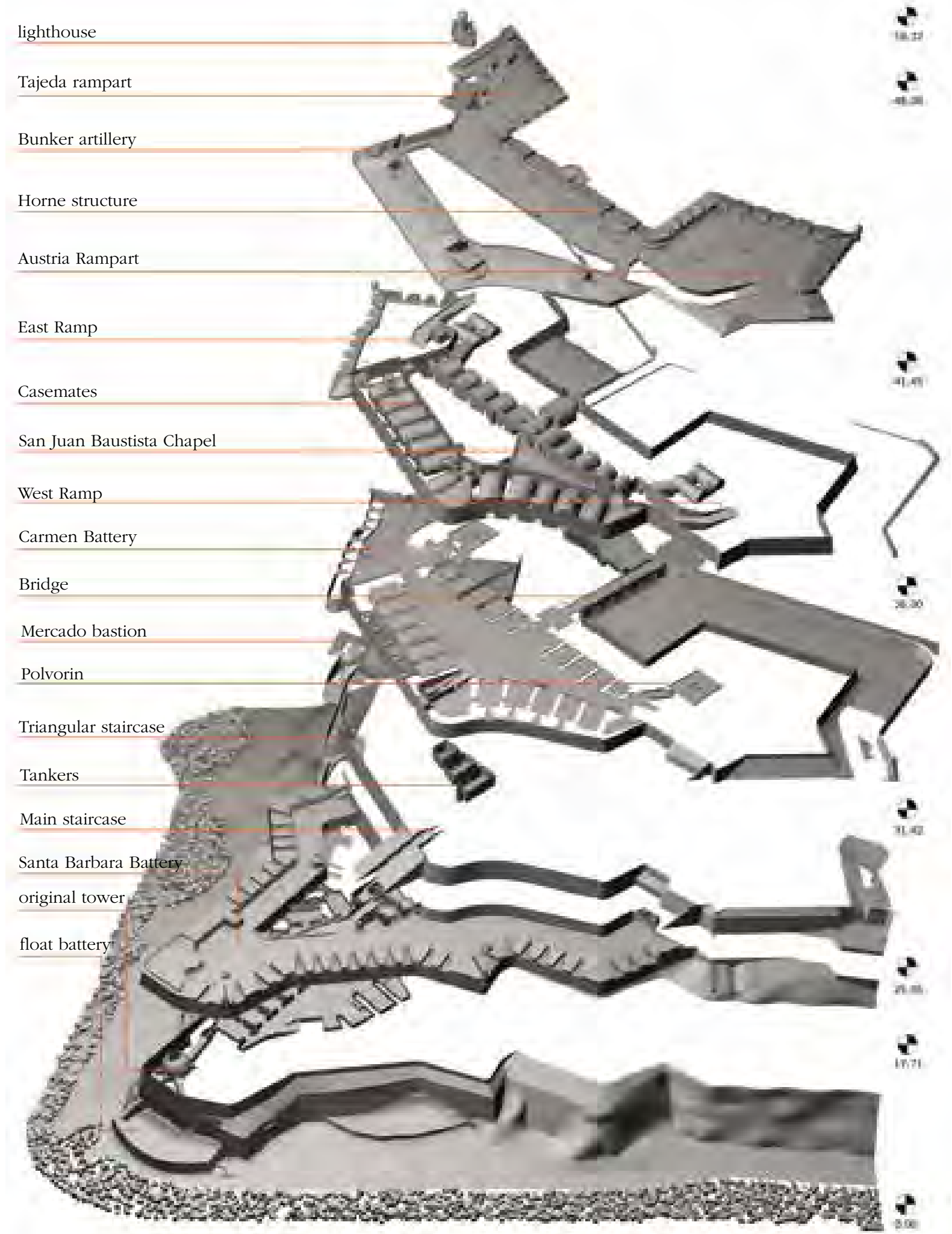
Tankers

Main staircase

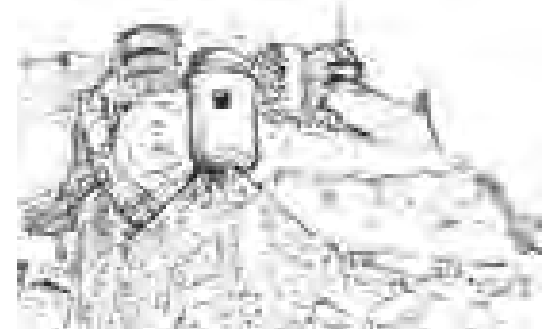
Santa Barbara Battery

original tower

float battery



The survey of the fortresses of San Juan in Porto Rico



SCIENTIFIC BOARD OF THE PROJECT

SANDRO PARRINELLO

PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE; UNIVERSITY OF PAVIA; UNIVERSITY OF PORTO RICO; NATIONAL PARK SERVICE OF SAN JUAN; ICOMOS-ICOFORT.

WHERE AND WHEN

SAN JUAN, PORTO RICO (USA), 2010

AIM OF THE PROJECT

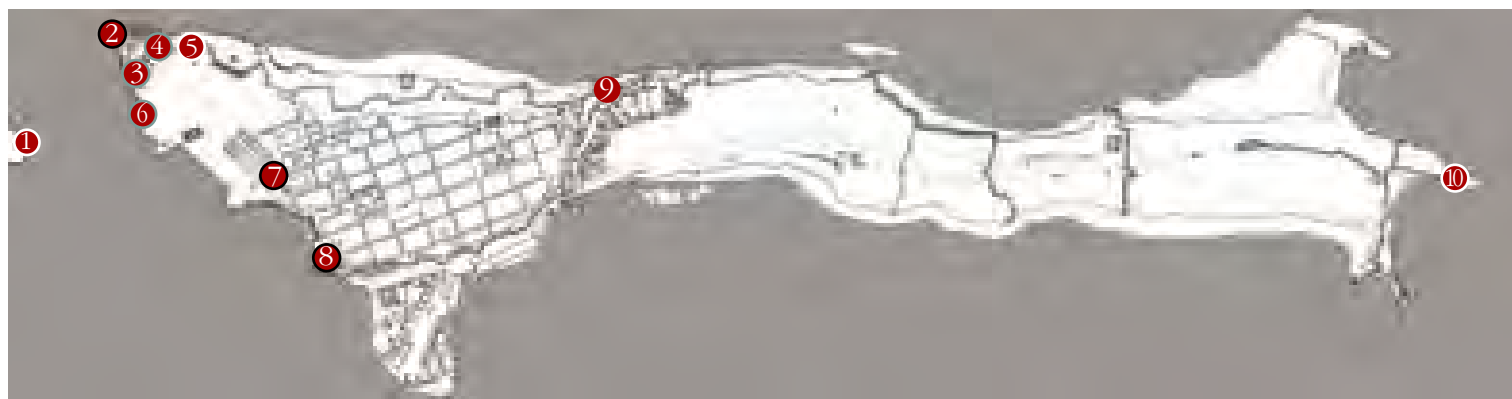
One of the most important defensive systems of the American continent is located on the island of Puerto Rico, close to its capital, San Juan, and it was declared World Heritage Site and managed by the national park service. The defensive system consists of an old castle that dates back to the early years of Spanish colonization, three minor fortresses and the defensive walls that surround the old town. The project involved the documentation of the fortresses and the realization of 3D models for the development of the architectural system.

The following case study, chosen for its similarity to the Morro of Havana and of Santiago, was the San Juan of Puerto Rico, where the project was supported by the structure of the National Service Parck through the relationships with the University of Porto Rico. During the ICOFORT 2010 annual meeting, that took place in the Fort of San Cristobal, determining also in this case an important connection and relationship with the most important experts of the Puerto Rican defence system participating to the event, the Italian research team was in charge of surveying the fortresses, testing a system of data collection and processing closely related to the restitution of threedimen-

sional measurements. In the project of Puerto Rico any information collected for the documentation of the castles was used in order to build an interactive platform where it could be possible a real-time netsurfing in the fortress and the virtual exploration of the high resolution 3D spaces, thus trying to develop a multidimensional design of the information system on the building.

The large size of the forts in the defensive system of San Juan required the determination of integrated methodologies for the control of the reliability metric drawings and the development of three-dimensional models in which to bring together all information pertaining to the status of the sites.





- 1 FORTE SAN JUAN DE LA CRUZ
- 2 TORRE DEL MORRO
- 3 BASTIONE AUSTRIA
- 4 BASTIONE TEJEDA
- 5 BASTIONE ANTONIO MOSQUERA
- 6 BASTIONE SANT'ELENA
- 7 CASA BLANCA
- 8 FORTALEZA DI SANTA CATALINA
- 9 CASTILLO DEL SAN CRISTOBAL
- 10 FORTE SAN GERONIMO



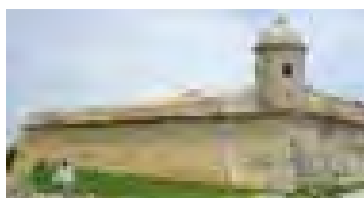
FORTIFICAZIONI PRESENTI TRA IL 1530 E IL 1582



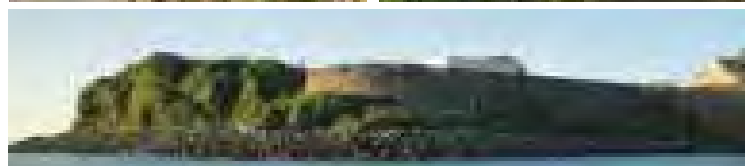
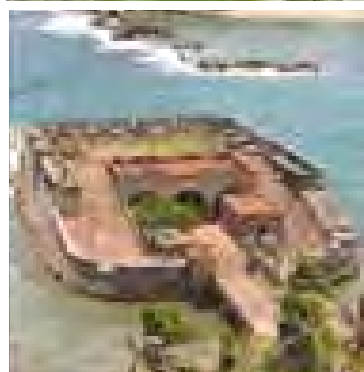
FORTIFICAZIONI PRESENTI TRA IL 1589 E IL 1595



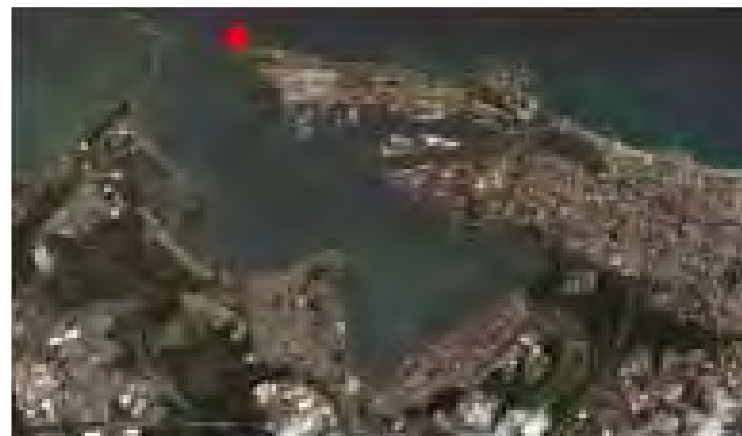
FORTIFICAZIONI PRESENTI TRA IL 1595 E IL 1610

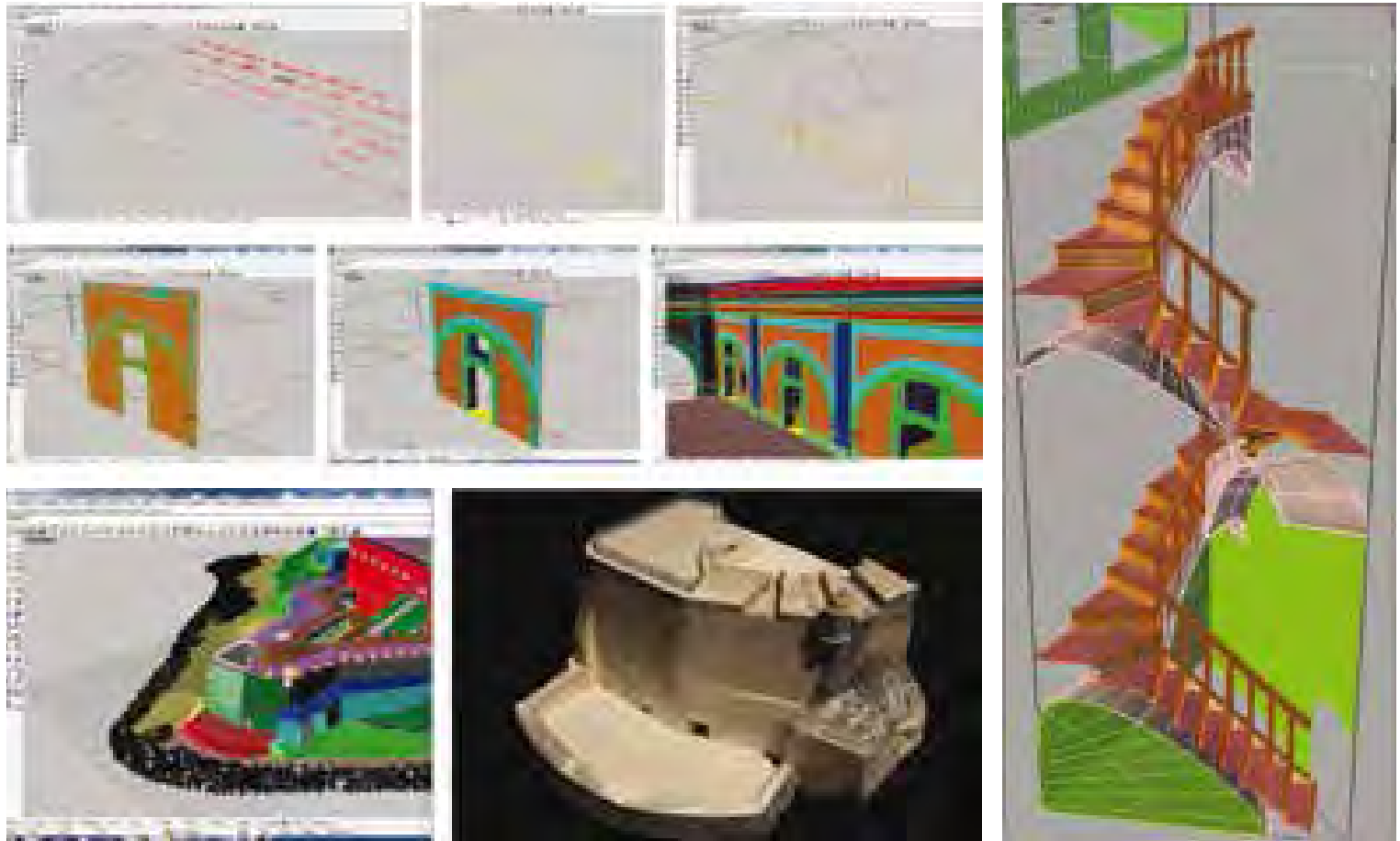


The Morro, located on the promontory at the end of the island, is the main element for the defense from the sea attacks. He was the first and the main defense system of the old city of San Juan.



Between the 15th and 19th centuries, a series of defensive structures was built at this strategic point in the Caribbean Sea to protect the city and the Bay of San Juan. The main elements of the massive fortification of San Juan are La Fortaleza, the three forts of San Felipe del Morro, San Cristóbal and San Juan de la Cruz (El Cañuelo), and a large portion of the City Wall, built between the 16th and 19th centuries to protect the city and the Bay of San Juan. They are characteristic examples of the historic methods of construction used in military architecture over this period, which adapted European designs and techniques to the special condi-





The three-dimensional model was constructed thanks to the two-dimensional plans and sections, modeled for small portions. Each item is in relationship with the drawings made during the survey campaign and the measurements taken directly on the object.

Each structural element was modeled with a detailed accuracy. So the stairs were divided in two parts: the vaults and the stairs elements.

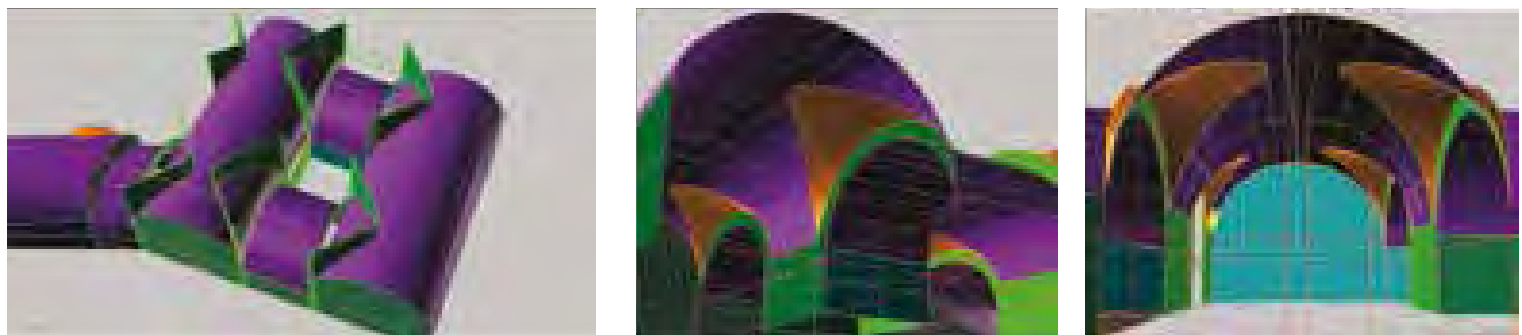


The program used to obtain a model extremely reliable and corresponding to reality is *McNeel Rhinoceros*. For giving a texture to the model has been used *Autodesk 3D Studio Max*.

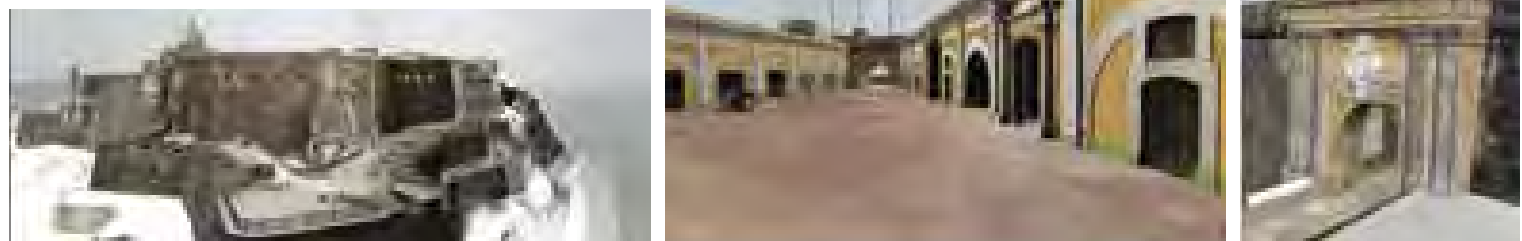


tions of the Caribbean port cities. La Fortaleza (founded in the early 16th century and considerably remodelled in later centuries) reflects developments in military architecture during its service over the centuries as a fortress, an arsenal, a prison, and residence of the Governor-General and today the Governor of Puerto Rico. El Morro, built to protect San Juan Bay, is situated on a rocky peak of land on the western extremity of the island.

The fort is a triangular bastion perfectly conceived according to the strategy of the second half of the 18th century, when it was entirely remodelled. It eventually developed into a masterpiece of military engineering with stout walls, carefully planned steps and ramps for moving men and artillery. By the end of the 18th century, more than 400 cannon defended the fort, making it almost impregnable.



Placement of plants to their corresponding elevations. After has been found common ground between elevation and plan necessary for the correction of photographic images.

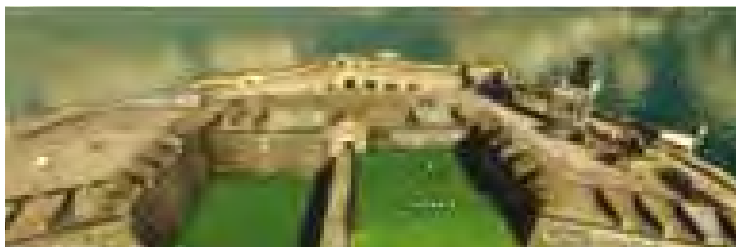




Sections with orthoimages elaborations for the description of the external walls of the structure.



Plan and 3D model of the fortress. The model was created to be completely textured in each surface. This reason and the complexity of the structure forced to divide and classify different layers each surface.



The model exported has been mapped with a UVW mapping system and exported again in two different software: *Cortona 3D* for the internet use and *Lumion* for render views.



Above: a view from model exported in *Cortona* software. The environment helps to make more realistic the whole scene.



The survey of the fortresses of Portobello



SCIENTIFIC BOARD OF THE PROJECT

SANDRO PARRINELLO

PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE; UNIVERSITY OF PAVIA; PATRONATO DE PORTOBELLO Y SAN LORENZO; MIT, MANZANILLO INTERNATIONAL TERMINAL; INAC, INSTITUTO NACIONAL DE CULTURA; PARQUE NACIONAL PORTOBELLO; FUNDACIÓN BAHÍA DE PORTOBELLO; MUNICIPALITY OF PORTOBELLO.

WHERE AND WHEN

PORTOBELLO, PANAMA, 2009 - IN PROGRESS

AIM OF THE PROJECT

Christopher Columbus discovered the bay of Portobello in 1502, during his fourth voyage to the Americas. The city was founded in 1597 and called San Felipe de Portobello in honour of Philip II, King of Spain. More than 11 defensive forts and batteries are present on the bay, built on a Battista Antonelli's draft for the defence of the important commercial port. Fortresses, located inside the humid tropical forest, were declared a World Heritage Site and the research project has focused on the survey of existing architectures and the development of systems for the protection and preservation of the UNESCO site, including the management of the urban and the environmental context.

The documentation for the knowledge and the enhancement of the bay of Portobello in Panama has began in December 2010 in collaboration with the Protectorate of Portobello and San Lorenzo in the province of Colon. The important relationship between the defence system and the structure of the village has made necessary a work of analysis extended to the social system present in the territory, realized through the cataloguing of the housing units and of the structure of the settlement system.

Antonelli's Spanish military architecture characterizes the first construction period (1596-99) and the neoclassical style of Salas and Hernandez (1753-60) dominated afterwards.

The Pan American Institute of Geography and History, along with other international organizations, already recognizes the

sites of Portobello and San Lorenzo El Real to be of universal importance; they are an essential link to an understanding of American history. The forts are however in a poor state of preservation.

The documentation work has focused on the recognition of all the fortresses and architectural survey of the ruins. The drawings have been reported highlighting the conditions of degradation and instability of individual fortresses thinking to the development of a general management plan for the UNESCO site. The strong naturalistic connotation of the site has a very important impact on the image of the monuments, survey operations have required the development of modeling systems for the return of the image of this important landscape.





Several technologies have been used for the architectural survey of these fortresses; laser scanners, photogrammetry, topographic and direct survey, are integrated together to explain the morphology of the ramparts and the walls.

The large number of measured data was used to build a 3D model of the city of Portobelo to use, as an interactive platform, for the construction of a virtual museum. The material produced was also thought to increase the museum present today in the building of the old customs.

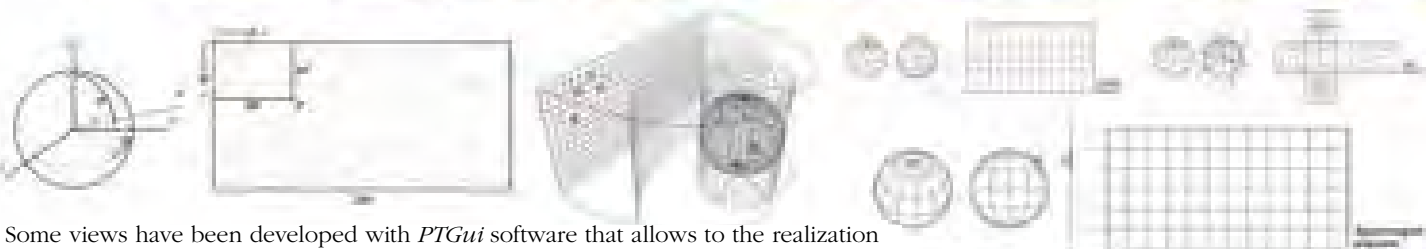
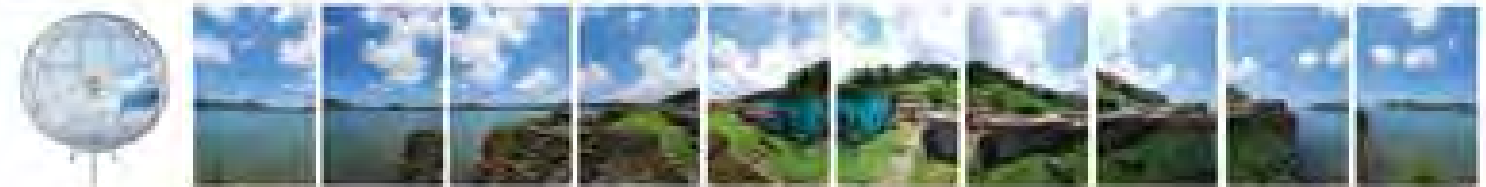
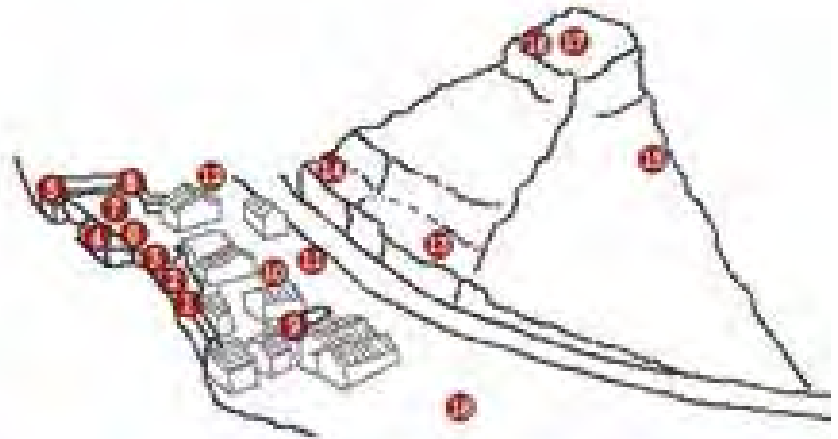
The forts of the bay work as a real organized system, there is always a reason related to the use of guns and visual trajectories that regulates the disposal of the fortresses. Studying these architectures corresponding to understand how they work with each other individual buildings, to understand what should be the historical image of this place and how it should take place the life in this natural harbor.





The documentation of the fortresses of the village of Portobelo has focused primarily on the integration of photogrammetric survey.

Structure from motion survey which allows us to create three-dimensional models from the pictures have been joined by the processing system of spherical panoramas made from common cameras, and joined together by a stitching software.



Some views have been developed with *PTGui* software that allows to the realization of planar, cylindrical and spherical panoramas.

Through software *poits records* and *Sphera* (by Prof. G.Fangi, Università of Ancona) the views are aligned on the basis of homologous points in the same scene and find the coordinates in three dimensional space necessary to reconstruct the scene.





SANTIAGO BATTERY

The survey of the fortress has provided two moments of documentation: one before the landslide that took place in December 2010 and one after that event.

Many of the environments presented a lots of difficulties for the accessibility.





General section of Santiago Battery.



External fronts of Casa Forte Santiago
On the left: Orthoimage plan of the Fort.



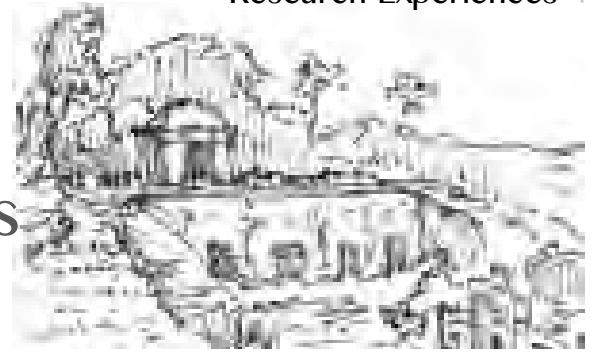
Render from *Lumion* of Casa Forte Santiago.



Sections of Casa Forte Santiago.



The survey of the fortresses of San Lorenzo el Real del Chagres



■ SCIENTIFIC BOARD OF THE PROJECT

SANDRO PARRINELLO

■ TECNICAL COORDINATOR OF THE PROJECT:

FRANCESCA PICCHIO

■ PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE; UNIVERSITY OF PAVIA; PATRONATO DE PORTOBELLO Y SAN LORENZO; MIT, MANZANILLO INTERNATIONAL TERMINAL; INAC, INSTITUTO NACIONAL DE CULTURA.

■ WHERE AND WHEN

COLON, PANAMA, 2012 - IN PROGRESS

■ AIM OF THE PROJECT

Chagres, once the most important Atlantic port on the Isthmus of Panama, is now an abandoned village inside the historical site of Fort San Lorenzo. The ruins of the fort and the village site are located about 8 miles (13 km) west of Colón, on a promontory overlooking the mouth of the Chagres River. In 1980, UNÉSCO declared Fort San Lorenzo, together with the fortified town of Portobelo, World Heritage Site under the name "Fortifications on the Caribbean Side of Panama.". The documentation project aims to study the historical ruins to determine the development of the UNESCO site.

The Chagres River, discovered by Christopher Columbus, is one of the most important rivers of the country. In the middle of its course there is the artificial Gatun Lake, that forms a major part of the Panama Canal.

At the time of the Spanish conquest, in the XVI century, the navigable waters of this river were part of the Camino de Cruces (the Road of the Crosses), crossing the isthmus and connecting the Caribbean coast and the Pacific one.

To protect the Atlantic coast from the pirates attacks was built Fort San Lorenzo at the Chagres River's mouth.

After Henry Morgan attack in 1670, the fort was left ruins. Thanks to the base of San Lorenzo, Morgan invaded Panama City the following year.

The UNESCO site of San Lorenzo fort is presently isolated within the humid tropical forest and it is accessible

through a partially collapsed street, a natural oasis where the ruins of the fort are located at the end of an evocative nature trail of this area. The way to arrive at the fort of San Lorenzo passes through the forest running along the Bay of Colón on the opposite side to the city.

The presence of ruins or remains of any settlements along the banks of the Chagres River and along the coast from the seashore to the mouth, was verified with a mission on a launch. In particular checking those sites that were described as settlement centres or defense systems in the historic cartography.

Land surveys were conducted around the fortress with the aim to document the historical routes that led from the mouth to the top of the fort.

These missions revealed the ancient Spanish routes, with some remains of the original flooring and paving.





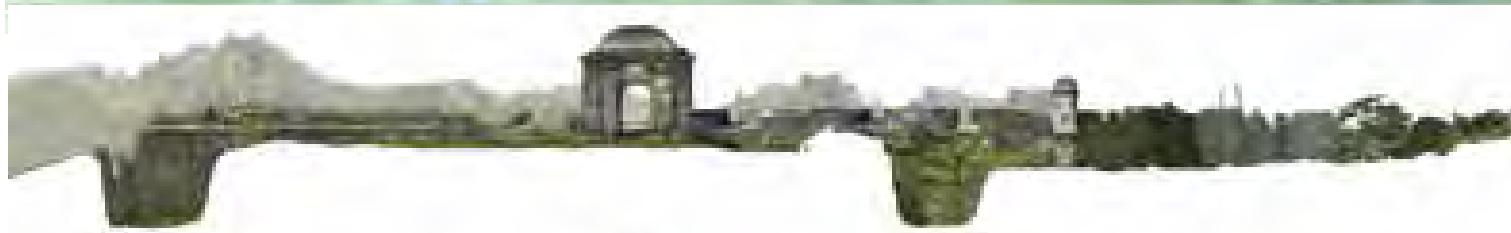
General context of the fortress. Aerial photo and general plan of the upper level. (Under) View of the environment from the launch. Main sections of the fort entrance.

From topographic stations we measured the targets attached to the fortress, and the most relevant points of the architectural elements, classifying masonry structures and individual architectural environments.

Besides the topographic survey, a photographic campaign was carried out, aimed at gathering qualitative data describing the state of preservation of the surfaces, and at the same time quantitative data to allow the achievement of highly reliable three-dimensional models.

The integrated survey, topographic and structure from motion, ensured the metric and quantitative reliability due to the precision of the topographic survey, and the qualitative metric one of the models generated by the series of bidimensional images, describing the state of preservation, besides the structural and morphometric quality of the architectural object.

The single frames are oriented with respect to the reference system, and the complete model is scaled down correctly thanks thanks to the targets in common between virtual models and topographic model, in order to aligned them, aiming at simplifying the drawing activities.

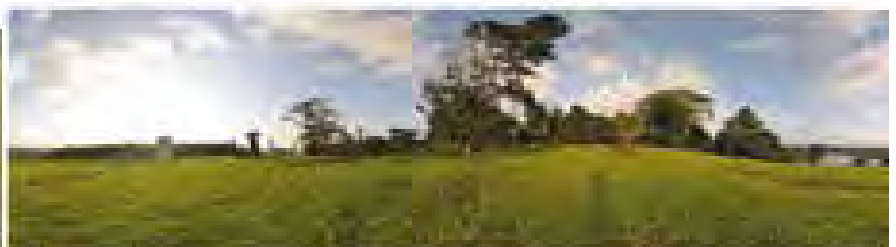




Through the use of devices for a direct survey of the whole architectural complex, we chose an horizontal section plane and a reference grid for the positioning of the targets. By means of a total station an highly descriptive topographic survey was carried out.



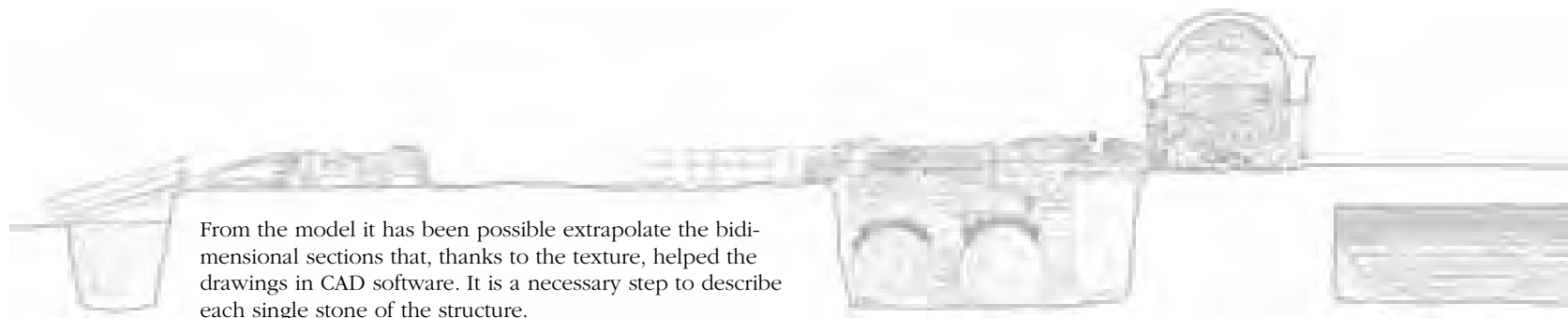
With a tripod and a rotating head for the camera we could take orbital pictures. These photographs can be visualized in 3D real-time space and in a virtual environment, providing an useful support to transform the site into a museum.



Using calibrated cameras it was possible to take pictures aiming at virtually modelling the whole building and its architectural elements present in the site.

By means of structure from motion procedures, we could reconstruct the virtual environments and the point clouds from a sequence of photos, using them as a tool to verify the topographic survey of each space, aligning the point clouds and the 3D models to the targets of the topographic point cloud.

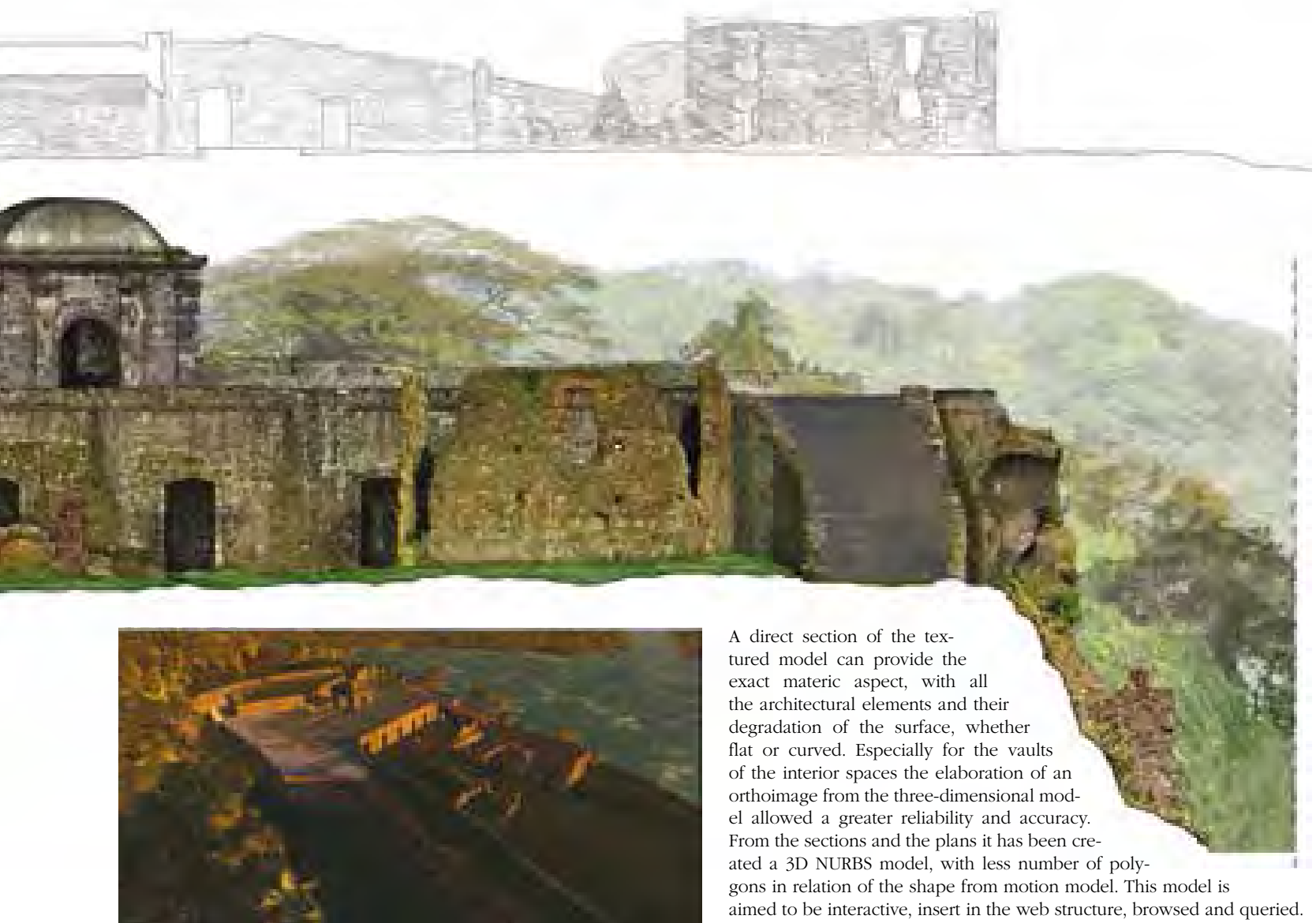




Besides the topographic survey, a photographic campaign was carried out, aimed at gathering qualitative data describing the state of preservation of the surfaces, and at the same time quantitative data to allow the achievement of highly reliable three-dimensional models. The texturing of the model has remarkable advantages to the purpose of processing the two-dimensional data.



It is important to organize a prior reconnaissance mission to better choose the position of the photographic shots. In order to use the photographic image as a qualifying element of the process complexity of data gathering and post-production of this project, it was useful to consider a different concept of technical descriptive drawing of historic architecture.



A direct section of the textured model can provide the exact materic aspect, with all the architectural elements and their degradation of the surface, whether flat or curved. Especially for the vaults of the interior spaces the elaboration of an orthoimage from the three-dimensional model allowed a greater reliability and accuracy. From the sections and the plans it has been created a 3D NURBS model, with less number of polygons in relation of the shape from motion model. This model is aimed to be interactive, insert in the web structure, browsed and queried.



Views of the 3D model with its environment.

The sections from the general three-dimensional model of the whole complex helped for the development of high-resolution orthoimages. From the modelling of the perimeter wall of the moat, it was possible to determine the exterior architectural elements of the complex. On the right: preparatory drawing and modelling of the structure of the entrance to the platform. The models have a better geometric accuracy also depending on the distance of the photographic device.

In case of the access structure, the accuracy on the side of the platform inside the fort is significantly more distant than the opposite one, and the photos were taken beyond the moat.



Survey methodologies for the front of the Ekaterina Palace in Pushkin



SCIENTIFIC BOARD OF THE PROJECT

STEFANO BERTOCCHI, SANDRO PARRINELLO

PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE; UNIVERSITY OF PAVIA; ATRIUM O.O.O.

WHERE AND WHEN

PUSHKIN, ST. PETERSBURG, RUSSIA, 2008

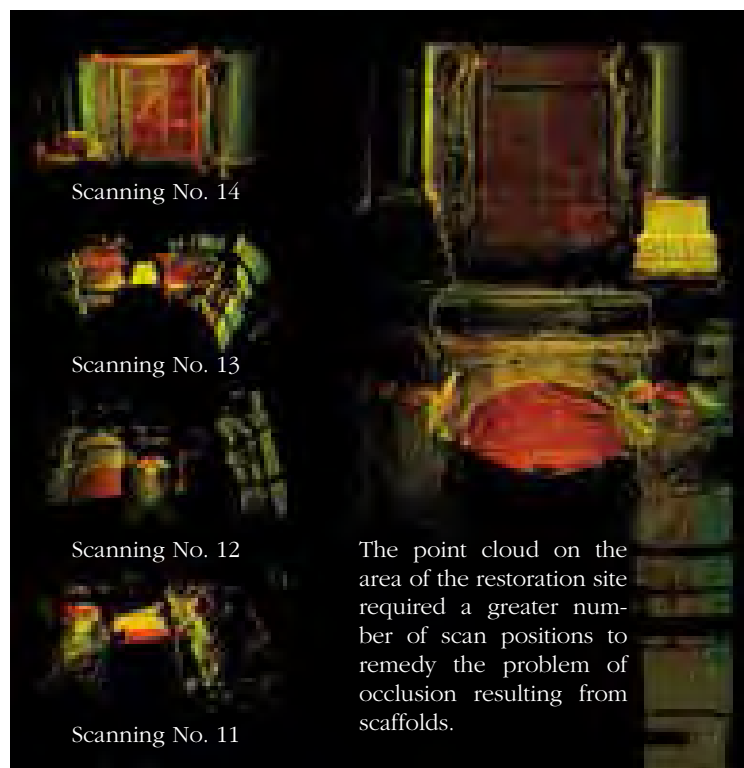
AIM OF THE PROJECT

The palace was the summer residence of the Tsars of Russia, in the village of Tsarskoye Selo (Pushkin), situated close to St. Petersburg. Elizabeth, niece of Peter the Great, in 1752, commissioned the Italian architect Rastrelli to rebuild it in the Rococo style. An experimental program for the restoration of the facades, promoted by Italian companies, realized the 3D laser scanner survey of the southern to create complex, high-resolution, photo-plans that formed the basis for documentation for the restoration activities of the palace.

Peter the Great at the beginning of the Great Northern War took possession of the Swedish outposts on the Neva river, and in 1703 founded the Fortress of Saints Peter and Paul on the river, a few miles from the sea. After the final defeat of the Swedes, at Poltava in 1709, the city which was called Sankt Pieter Burkh began to grow. Canals were dug to drain the marshy south bank of the river and, in 1712, the town was proclaimed the capital of Russia. Architects and craftsmen from all over Europe were called into the city. Between 1741 and 1825, under the government of Elizabeth, Catherine the Great and Alexander I, the city became cosmopolitan and had a court known splendour. These monarchs commissioned in fact many palaces, government buildings and churches, making St. Petersburg one of the most important capitals of Europe. Some of the most important imperial residences built in St. Petersburg and surroundings were, first of all, the Winter Palace and the Summer Palace, both subsequently demolished around 1797; the Grand Palace of Petrhof was the result of a massive restructuring in 1747. We can cite

also four other buildings that contributed to the enrichment of the scene of the city of St. Petersburg: the Vorontsov Palace built in 1749, the Catherine Palace in Tsarskoye Selo realized in 1752, the Stroganov Palace and the Winter Palace built in 1753. The palace of Catherine, rococo in style, was the summer residence the Tsar of Russia in the village of Tsarskoye Selo, now called Pushkin, located about 25 km south-east of St. Petersburg. The birth of the palace complex of Ekaterina and the park dates back to the seventeenth century. In 1710 Peter the Great gave the land to his wife Catherine who in 1717 ordered the construction of a prestigious summer residence. But already in 1743 the Empress Anna ordered the architects and Zemtov Kvasov to expand the building that now had taken the name from his mother, Catherine. The grandson of Catherine, Elizabeth, thought to a new place in the palace, and in May 1752 he asked the court architect, the Italian Rastrelli (designer of the City of St. Petersburg and many prestigious buildings) to demolish and replace with an even more magnificent building, in a rococo style.





The point cloud on the area of the restoration site required a greater number of scan positions to remedy the problem of occlusion resulting from scaffolds.

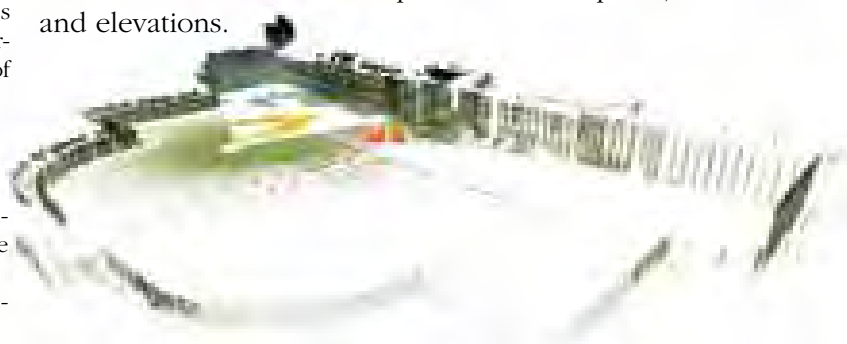


Scheme of the positioning of the laser scanner. The morphological complexity of the face requires many scans to cover all the surfaces in relation to the radius of incidence of the laser.

Beside: The cloud of points relative to the portion of the facade detected.

Under: an image scan of the facade of the palace.

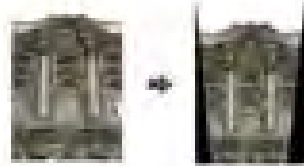
The survey was aimed at testing of laser scanners 3D for creating photo-plans detail of the complex system with gilded stucco decoration of the main facade of the palace. It is a front articulated on buildings alternately projecting and falling, and smaller wings on the sides that surround three sides of the square of great access to the strap. All bodies are decorated with a giant order, in the round, with pilasters of riveted, lying on a high pedestal in imitation ashlar. Large telamons stucco, willing to basement floor, support the columns of the giant order of the upper floors in some areas of the facade. The survey project was targeted, in addition to the restitution of all the facades and the photographic plans of the portion subjected to the restoration, to the creation of 3D models of various parts also reliable decorative stucco that had to be restored with the original decoration gold leaf. The data acquired during the campaign of 3D laser scanner survey, because of the large extension of the monumental complex, have used the support of the topographic survey of the complex of targets aimed to the registration of the scans. After verifying the reliability of the reference system of the targets and recorded the point clouds from individual scans we proceeded to the 2D drawings of the survey, through the extraction of useful sections to reliable representation of plans, sections and elevations.





To the left of an image formed by the cloud of points of a module of the façade regarding the portion between the two columns.

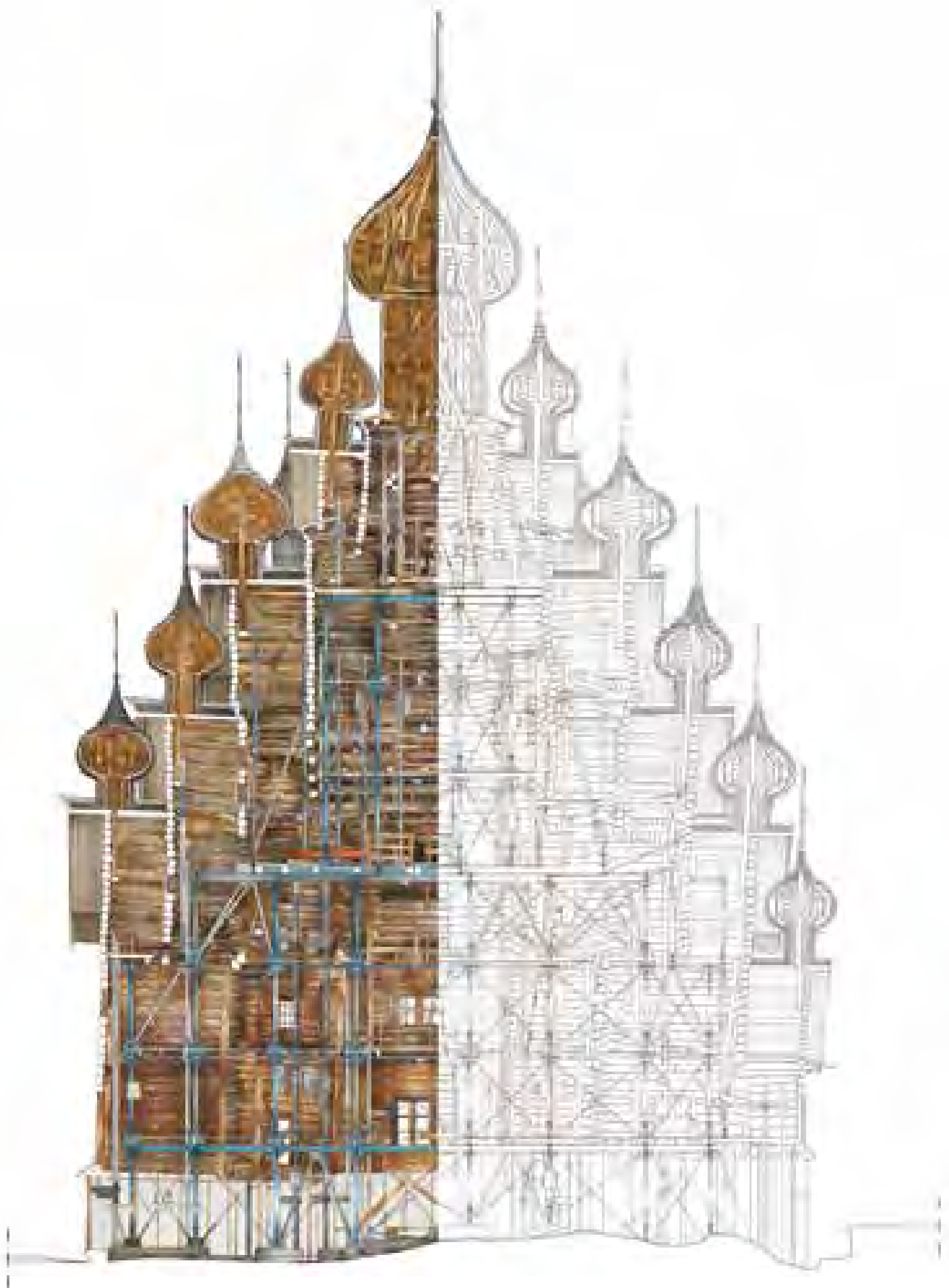
On the right: redrawing of the front in Autocad; the complexity of the drawing focuses on the ornamental elements that correspond with the parts of the front in gold.



Processing orthophotos separating the architectural elements and using the point cloud as the basis for the control of individual deformations or variations of the architectural elements compared to the geometrical proportions of the system.

Below: the drawing of telamons, from the point cloud to “wire frame” in Autocad.





Laser scanner survey of the Pogost Complex in the Kizhi Island



■ SCIENTIFIC BOARD OF THE PROJECT

STEFANO BERTOCCHI, SANDRO PARRINELLO

■ TECHNICAL COORDINATOR OF THE PROJECT:

SARA PORZILLI

■ PARTNERSHIP/INVOLVED INSTITUTION

UNIVERSITY OF FLORENCE; UNIVERSITY OF PAVIA; KIZHI STATE OPEN-AIR MUSEUM OF HISTORY, ARCHITECTURE AND ETHNOGRAPHY, ATRIUM O.O.O.

■ WHERE AND WHEN

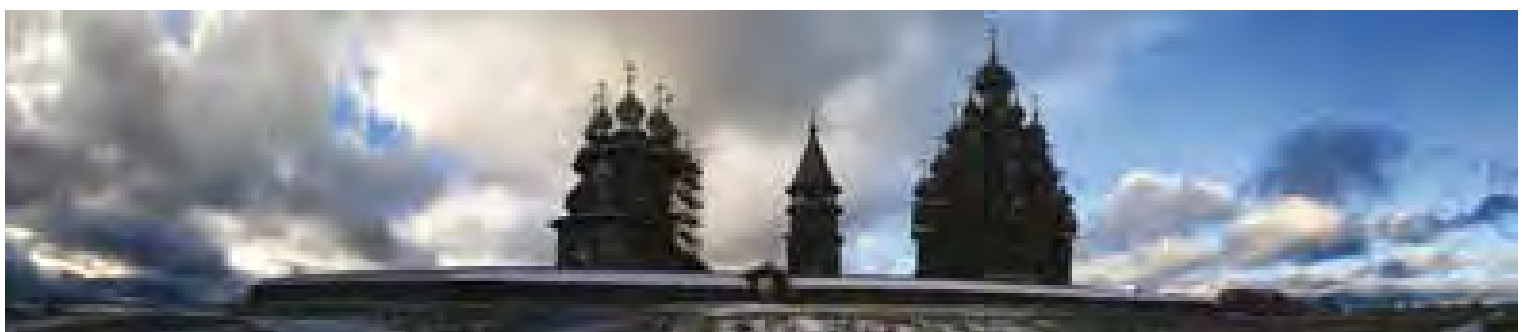
KIZHI ISLAND, KARELIA, RUSSIA

■ AIM OF THE PROJECT

The project concerns the Pogost complex, with a detailed and accurate analysis of the architectural and static structure of the Church of Transfiguration for the study of conservative and restorative methodologies. The project focuses on general survey of the object through different methods: laser scanner survey, direct survey, general analysis, realization of a wide photographic campaign and detailed drawings analyzing from the general to the detail. The results consist in 2D and 3D drawings, digital databases, census archives and 3D reconstructions.

Kizhi is one of the about one-thousand- five-hundred islands situated on Onega Lake in Karelia Region (Russian Federation). This archipelago took the name of «Zaonežie Iliade» probably for the special good climate and wealth of the environmental lands. Kizhi Island became the main administrative, religious and social center for all the territory thanks to its strategic, central geographical position and for the general good quality of the life. That's the reason why the population decided to build a Pogost Complex for control and manage all the lands of the archipelago. The complex consists of two churches, the main one is the Church of the Transfiguration (1714), the Church of the Intercession (1764) and the bell tower (1874). These architectures became quickly an expression of the great talent of carelian carpenters. After the first rich period, due to the abolition

of the private property increase and improve the migration of the dwellings from the countryside to the urban cities weakened the agricultural activities; the rural villages were abandoned and the wooden architectures started to be damaged. After that period of crisis, in 1966 on the island was established an open-air museum, where most of the traditional wooden architectures from different parts of Karelia where dismantled and reassembled on the island for guaranteed their conservations and protection. From 1990 the south part of Kizhi Island (where is collocated the monumental complex) became definitely part of the list of UNESCO World Heritage Sites, considered a World Heritage site because of the presence of unique historical architectures, characterized by structural and wooden technological systems typical and valuable of the Karelian territory.



Previous page: architectural section of the Church of the Transfiguration. Above: Image of the complex of Kizhi Pogost.



The research programme for this site consist in two different scale of analysis: the first step of the activities has included the survey project and analysis and postproduction elaborations of all the south part of the island for the study of the context and for the environmental areas, the second ones has gone deeper into the technical analysis of the Church of the Transfiguration. This church must be interpreted as a large structural complex formed and composed by wooden and metallic elements connected to each other by constructive different technologies that use different types of nodes and connective parts. The purpose of the research is to study this object through the use of scientific instruments that allows to understand exactly all the morphological qualities, the physical, spatial, and technological elements present for understand the best solutions for conservation and restoration of itself. The research activities has had two main purposes: study and documentation of the heritage (realizing the global 3D point clouds model of the entire area, realizing all the post production drawings and analysis) and the second one consisted in survey experimentations for understand which are actually the main survey procedures

Clouds of points that describe the relationship between the complex and the skyline of the island and the village of Yamka. Above: two images that describe the landscape of the island and its transformation following the establishment of the museum.





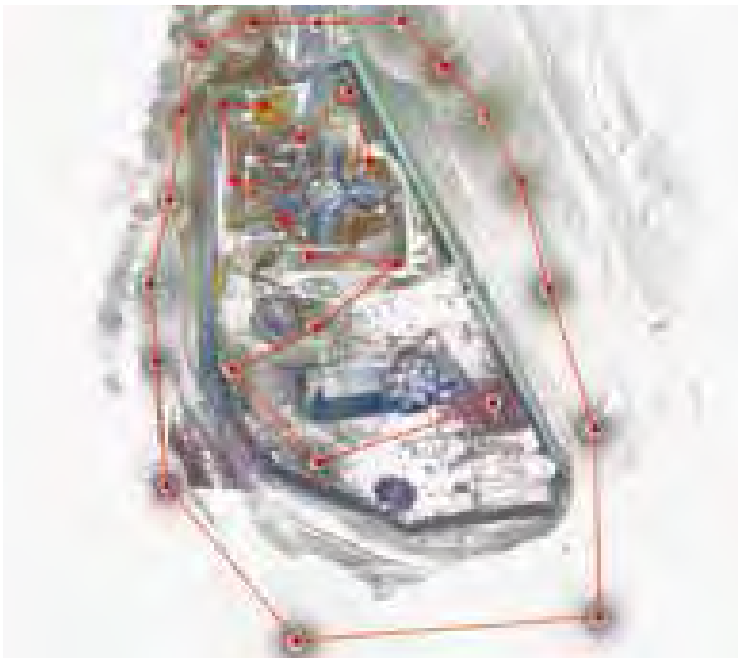
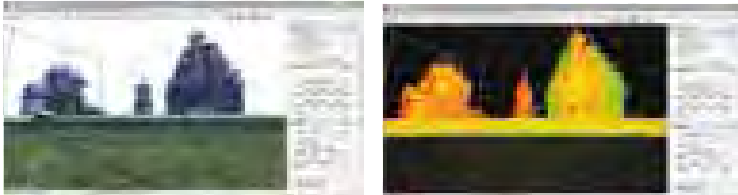
useful for study and survey wooden architectures increasing methodologies for conservation and restoration. The survey focuses on general survey of the object through different methods: laser scanner survey, direct survey, general analysis, realization of a wide photographic and pictures campaign, drawings for studies from the general to the particular analysis. After a detailed campaign of data capture, a series of explanatory drawings was carried out for understanding the functioning of the structure. Special attention was paid to the architectonical structure of the wooden architecture in relationship with a second internal metal structure, inserted during the period around 195 because of the first signs of structural failure of the church. These two systems of structures (wood and metal) over time have started to interact and rely on each other distorting the original architectural static system and producing significant deformations and static changes on the structure of the church, currently submitted on a delicate intervention of restoration. For all these reasons it was necessary to test the potential of a laser scanner survey planning stages of acquisition of the data, the survey,

critical evaluation of the information obtained and methodological procedures for the graphical restitution. The phases of the research project integrated 3D laser scanner survey are: 1. Three-dimensional survey with the integrated 3D laser surveying of the complex internal and external, consisting of a database format with Cyclone 6.0 © original scans, scanning images, recorded overall model, developed for architectural homogeneous areas; 2. Internal floor plans for each internal level, they are 1:50 scale. The return of the data collected is done with special software that, based on interrogation of 3D data recorded in a unique coordinate system, allows you to extract tracks at an altitude of default under Section 2D CAD environment and export the contents for the metric return of processed 2D CAD; 3. Sections: scale developed in 2D CAD is expected with a detail equal to 1:50. The projection parts (internal reports) are returned in integrating CAD 2D 3D data with the use of partial picture. 4. Sections of detail: the precise control of critical points of the structure were carried out in elaborate detail with a detail of 2D CAD to 1:20.

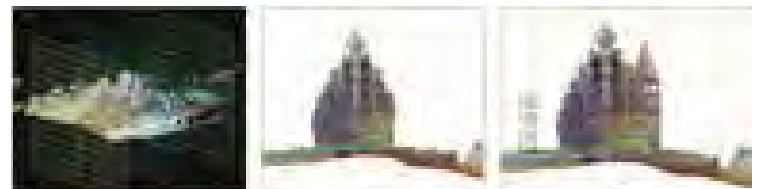


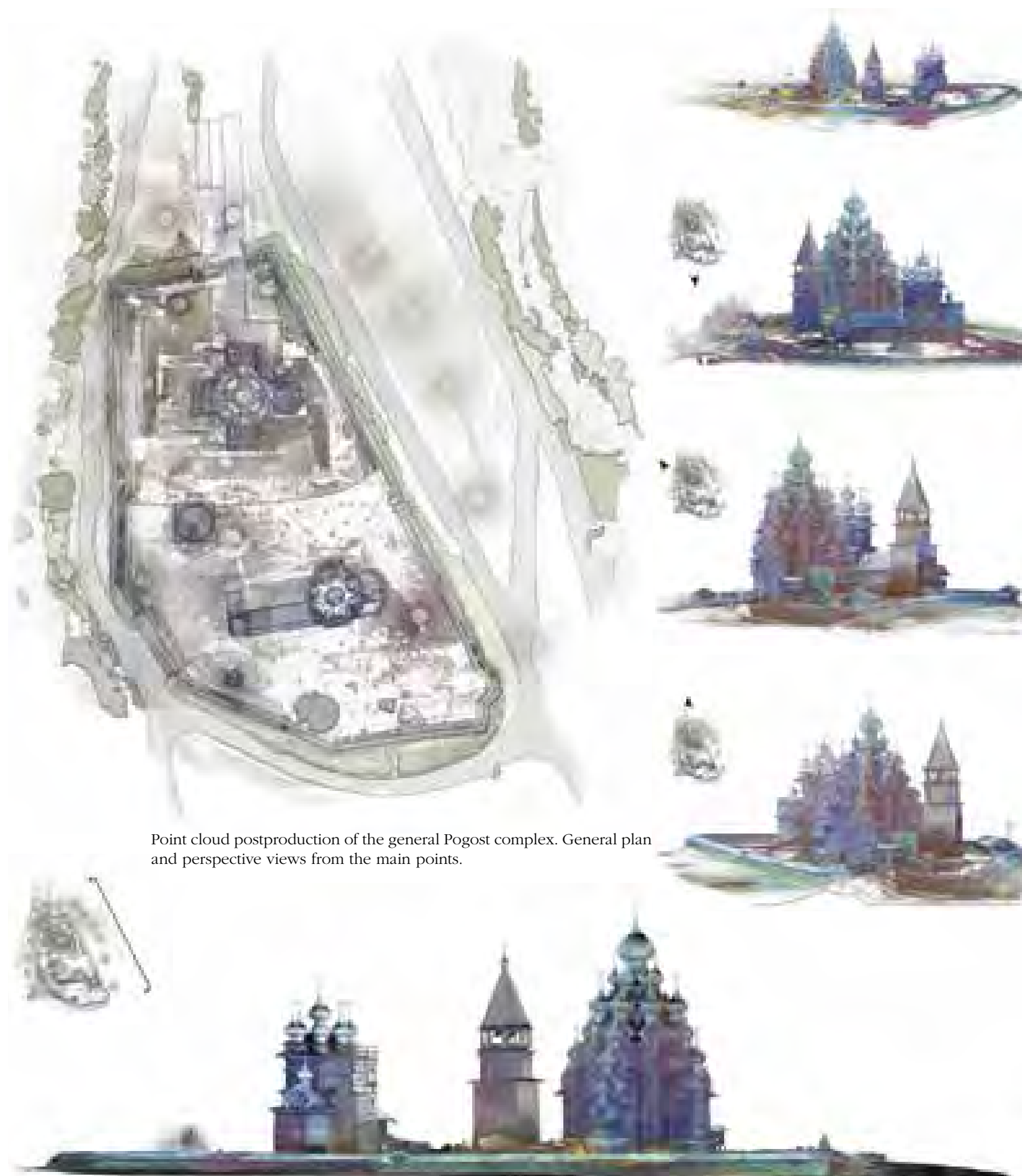


Survey activities with the Laser Scanner.



The scanner obtains firstly a panoramic shot of the object, then links the point cloud to the RGB value of the true point colour. After the primary scan, when scanner has obtained all points measures through laser ray, the thickening of the cloud has been made with additional scans of significant or problematic details. The laser scanner survey (during the data capture and in the graphic design after) allowed to value the reliability in the measurement control. It allowed to test its control related to the context, to the singular constructive details, to the resistance of every element of the building and, finally, to the displacement of the architectonic parts. To complete the first work step was conducted a study on structural details, intersections and wood elements assembling systems, in order to obtain a good knowledge of the features and issues about that architecture, to complete the survey data with appropriate critical skills, analysis and reprocessing. Such operations must provide the documentary basis for the preparation of thematic maps with the creation of digital database containing the results of studies on aspects of matter, the degradation, as well as on the chemical-physical and technological status. The proposal for these operations is focused on choosing a type of survey performed by 3D laser scanner for three-dimensional processes that can be able to join a high degree of reliability and reduced time for data acquisition. The definition of related diagnostic pictures of the church appears to be a fundamental activity to define concretely the state of deterioration and structural condition of the building.



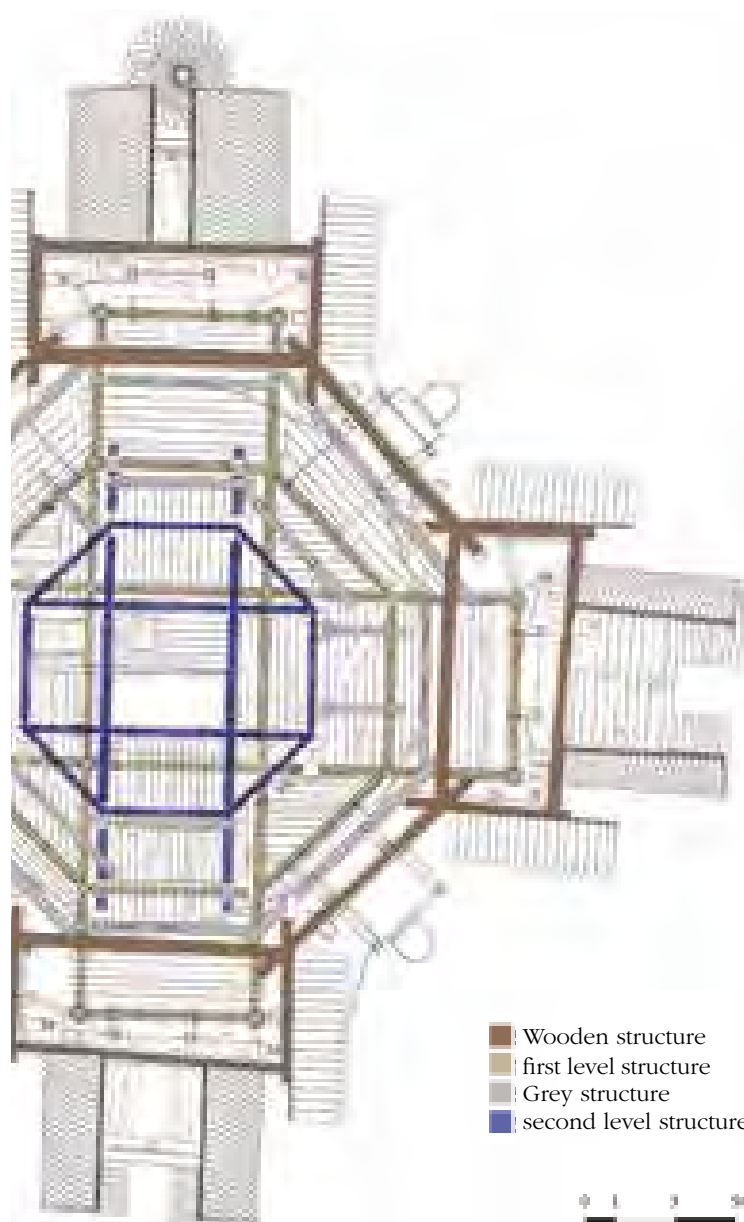


Point cloud postproduction of the general Pogost complex. General plan and perspective views from the main points.





General view of the point cloud of the Church of the Transfiguration. Bottom: detail views of the point cloud of the church interior.



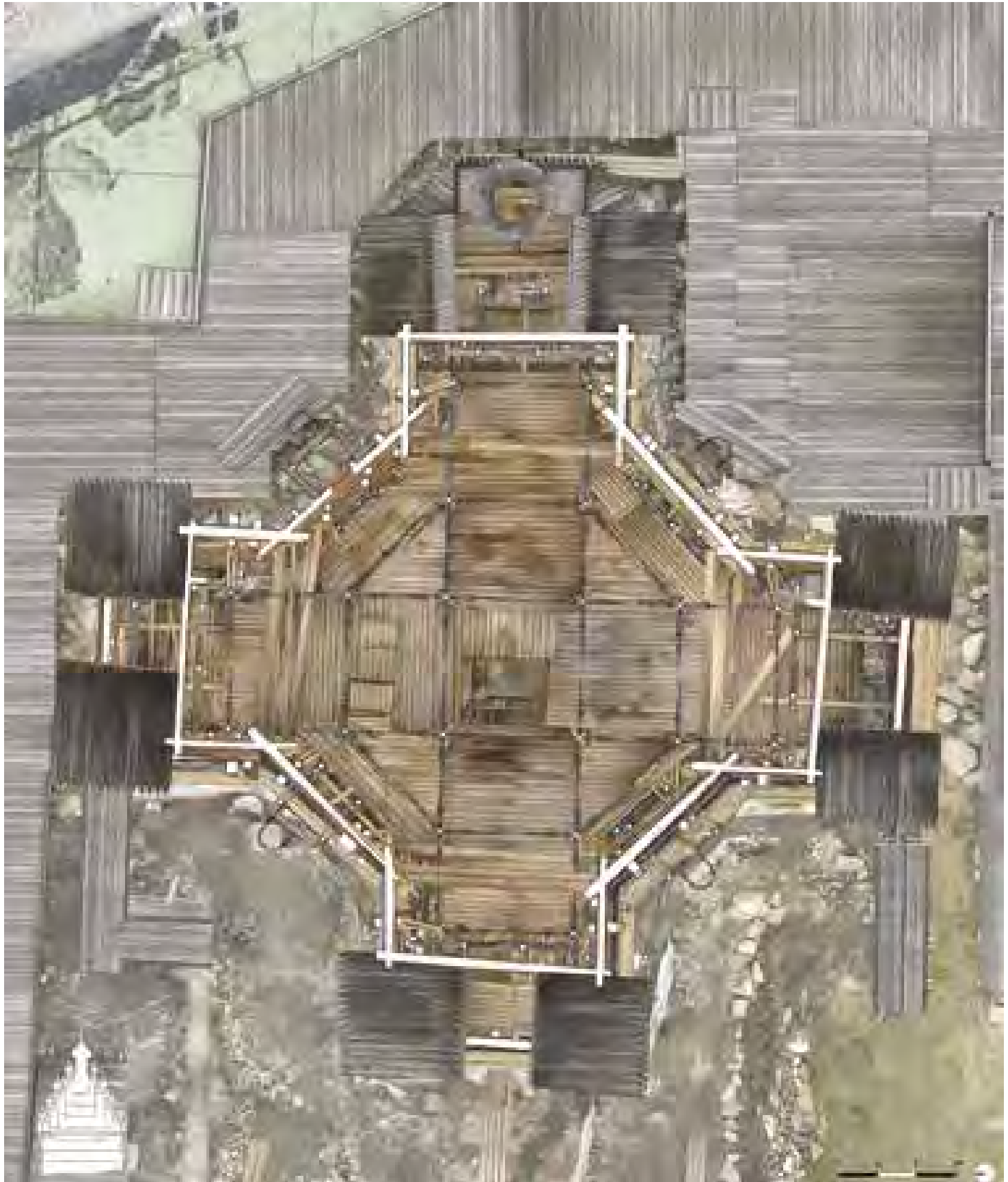
The database has processed the purpose of obtaining consistently useful information systems for the management and construction of an integrated complex model of analysis on architectural system and structural elements. The preparation of drawings has consisted in realization of detailed plans at any level of the structure, vertical sections on each plate of beams, axonometric drawings able to show the relationships between each floor, represent the general architectural aspects of the first phase and the main knowledge-diagnostics of the project. The graphic re-elaborations are accompanied by a diagnostic framework and a mapping of the degradation that give the possibility to explore the most interesting geometrical sections of each wooden element, becoming a real thematic maps where it could be possible to read a whole different characteristics which affect the product. The construction of three-dimensional models then complete the overall objectives of the project. These models do not have the sole purpose of being useful to graphic material representation of this monumental complex, but most want to be seen as dynamic database and always upgradable, integrating with modern management systems, GIS on which articulate throughout the insertion of diagnostic data. The three-dimensional model can become navigable and interrogated in each of their parts like a “virtual book or booklet graphic campaign” constantly consulted and updated constantly in order to obtain information on the progress of the restoration of the church.

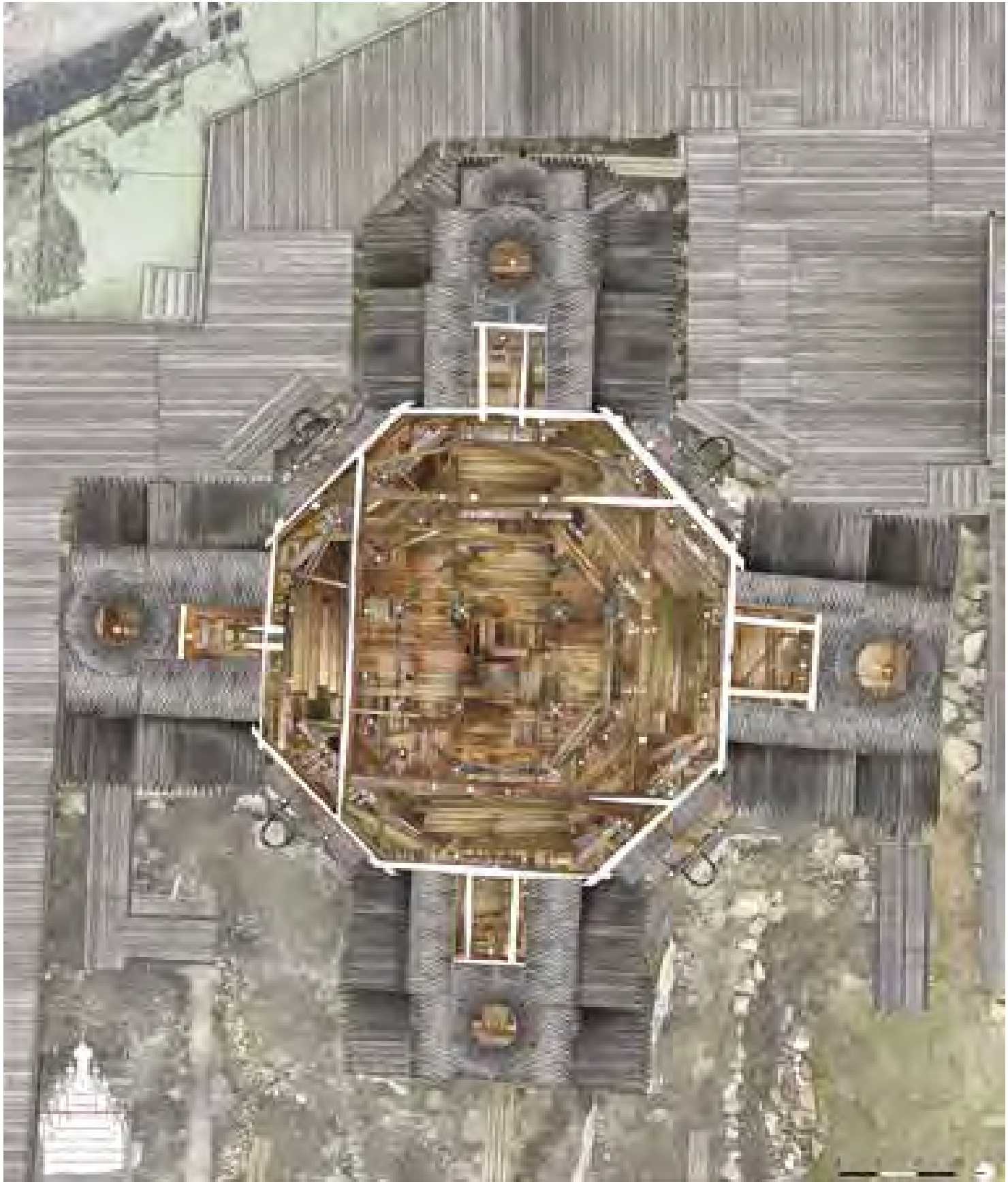
For each level of the construction site have been developed horizontal sections with 2D vector drawing and orthoimages.



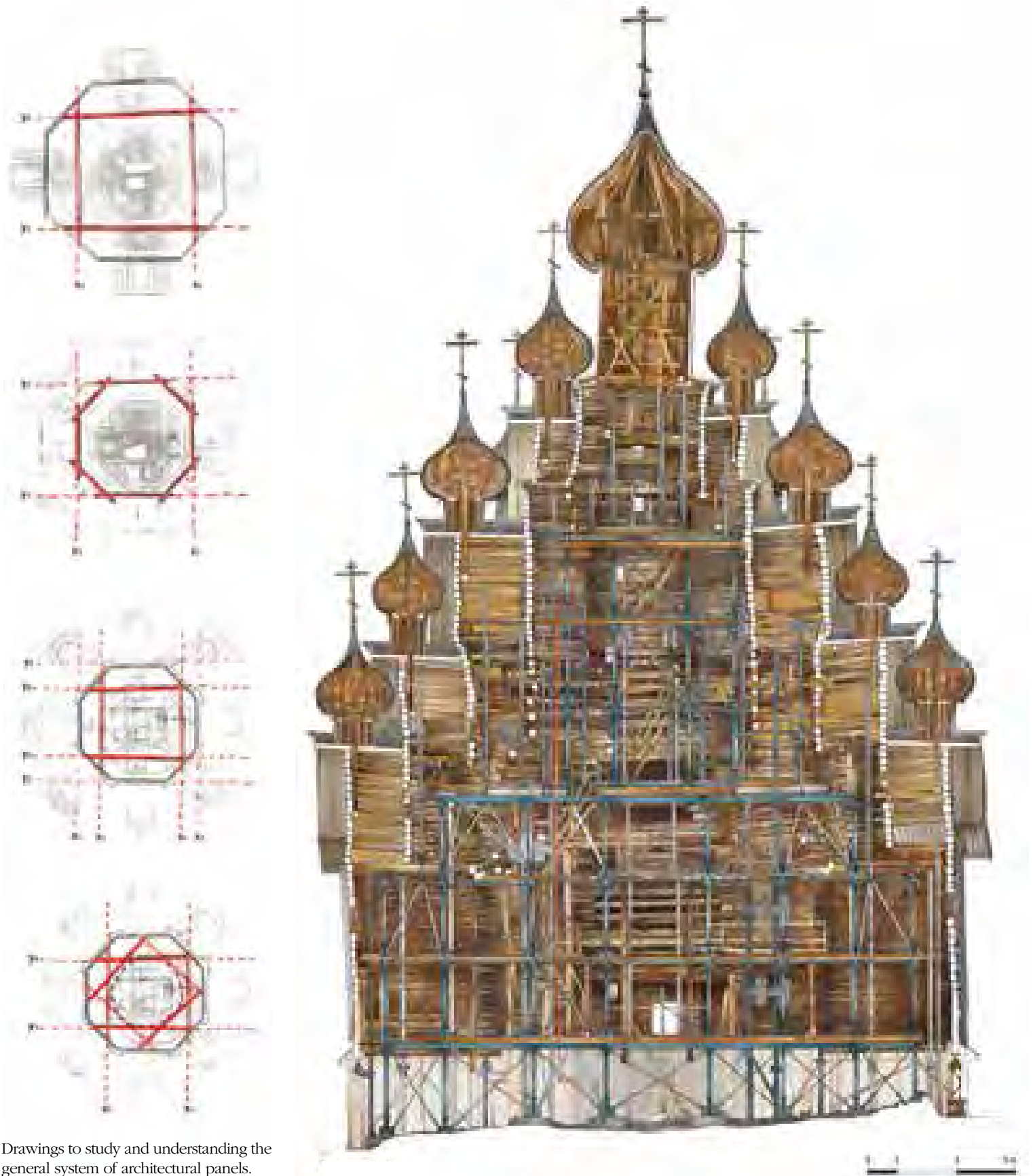




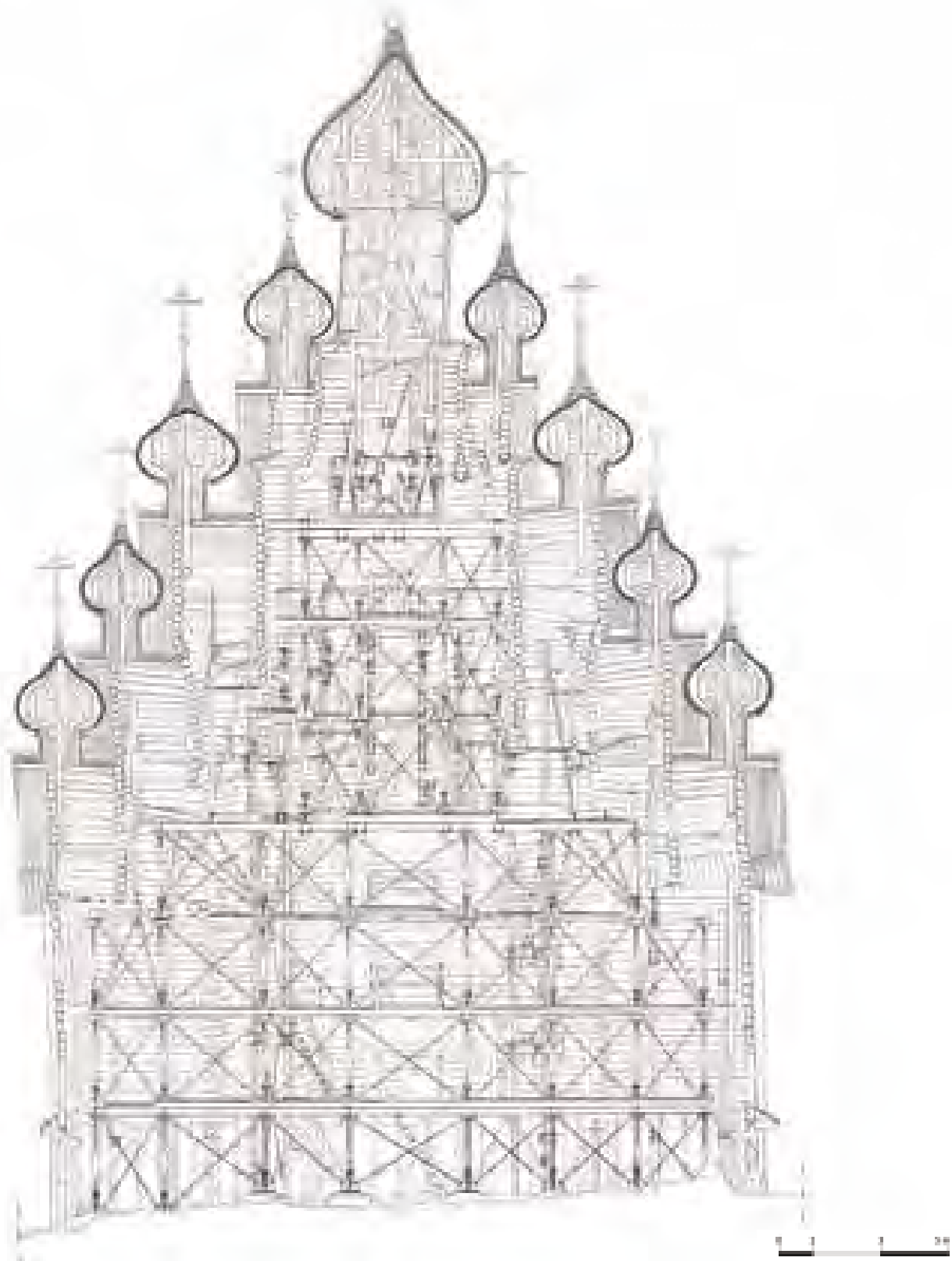


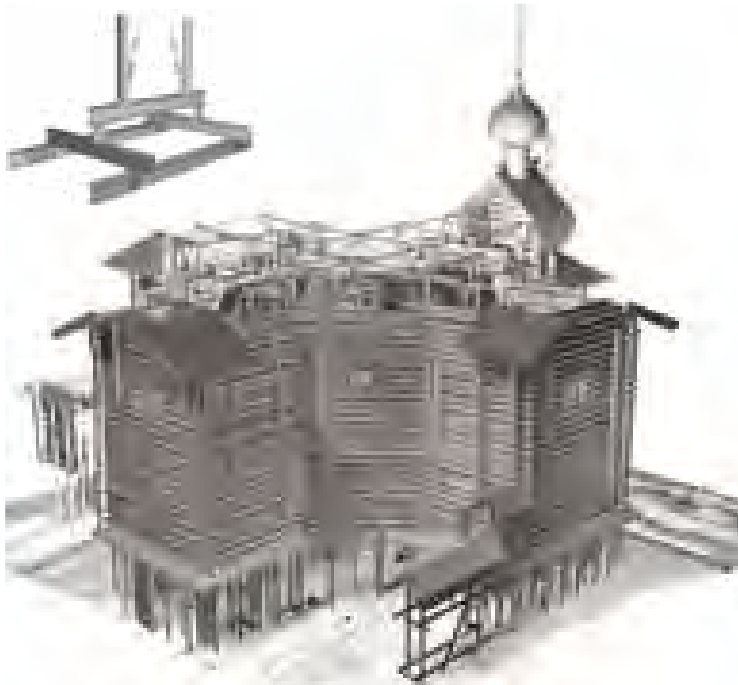






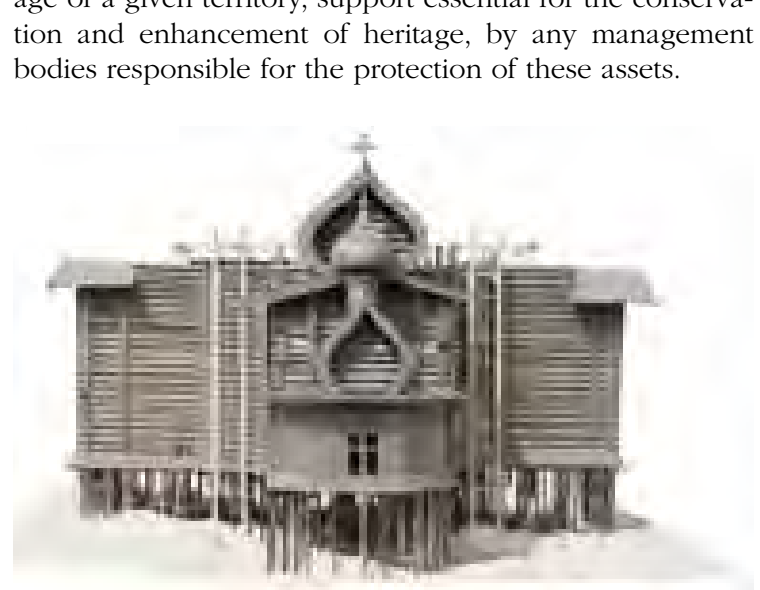
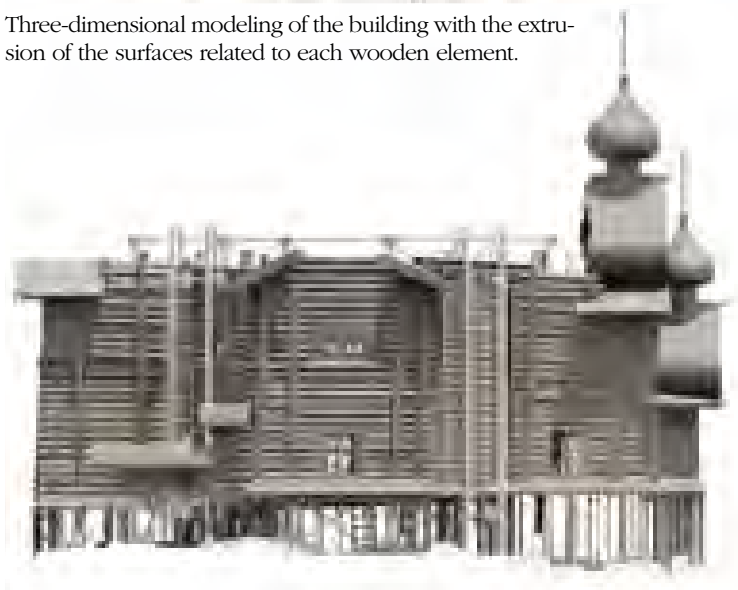
Drawings to study and understanding the general system of architectural panels.

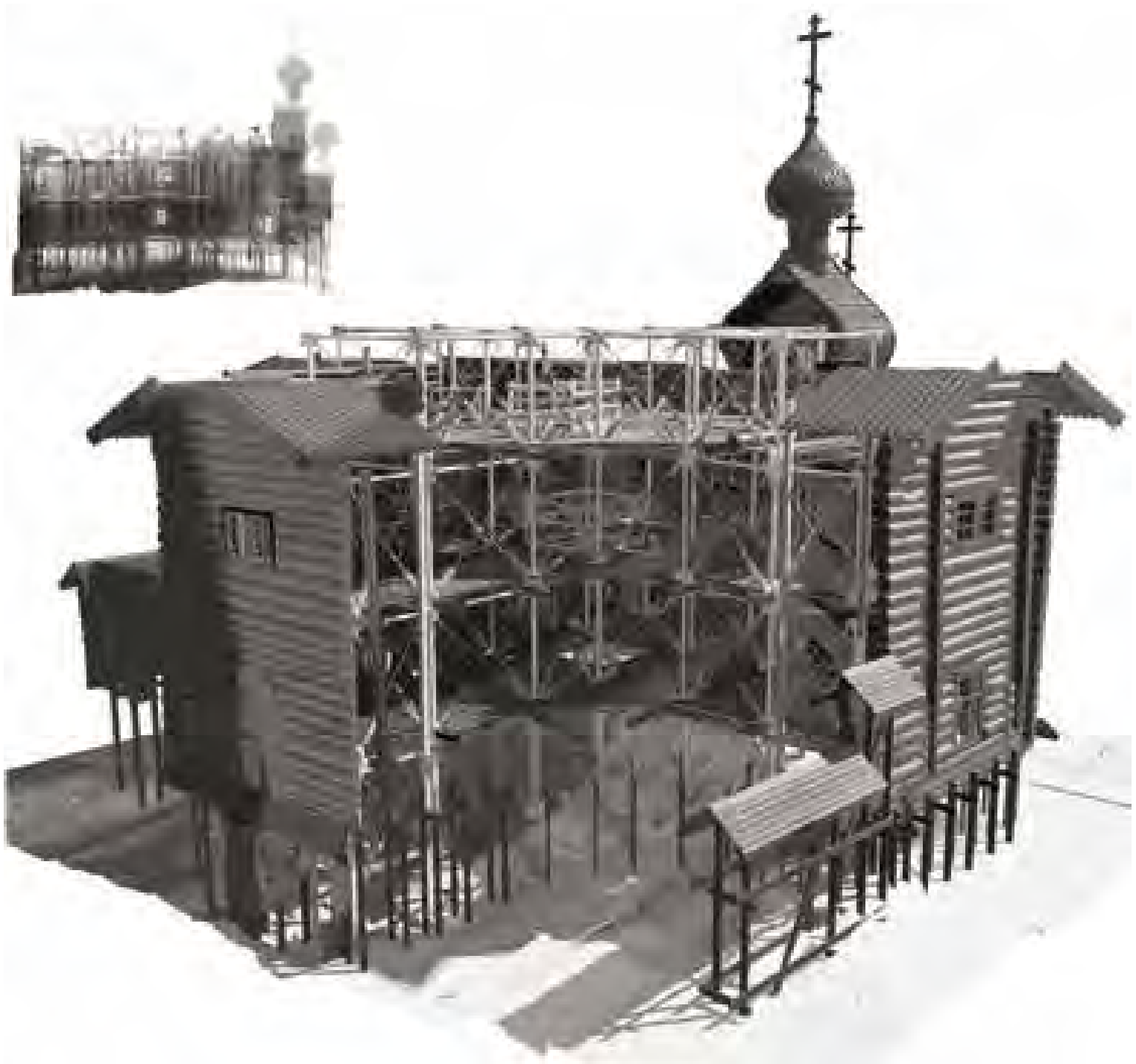




Three-dimensional modeling of the building with the extrusion of the surfaces related to each wooden element.

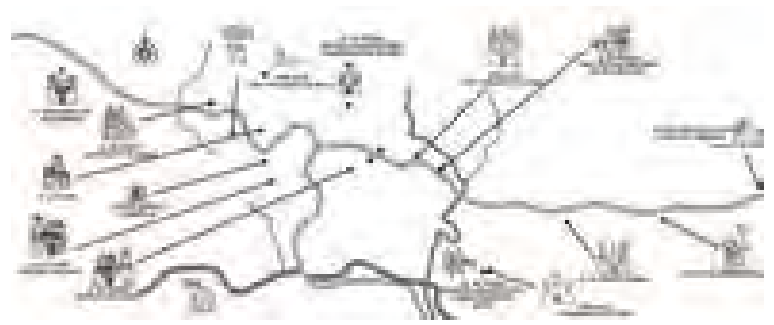
The definition of diagnostic thematic maps about the church appears to be a fundamental activity to concretely define the state of deterioration and structural conditions of the building. The final drawings, metric databases and photo archives are designed to give a practical support to the analysis and work activities to technical operators and restorers, moreover the three-dimensional model of the church and the thematic maps give the possibility to have a complete scientific detailed recognition of the entire structure. The final database has the main purpose to define the procedures for realize functional restoration planning, which can be provided on the Karelian wooden architecture. Finally, simulation and design of a system of documentation and communication of restoration through 3D GIS technologies and multimedia systems capable of implementing and further developing the three-dimensional representation. The data collected and processed products during the course of the activities constitute an important basis for the establishment of archives on the cultural heritage of a given territory, support essential for the conservation and enhancement of heritage, by any management bodies responsible for the protection of these assets.







The 3D survey of baroque church and architecture in Ouro Preto



SCIENTIFIC BOARD OF THE PROJECT	STEFANO BERTOCCHI
TECNICAL COORDINATOR OF THE PROJECT:	GRAZIELLA DEL DUCA
PARTNERSHIP/INVOLVED INSTITUTION	UNIVERSITY OF FLORENCE; FEDERAL UNIVERSITY OF MINAS GERAIS (UFMG); POLYTECHNIC UNIVERSITY OF MADRID (UPM).
WHERE AND WHEN	OURO PRETO, MINAS GERAIS, BRAZIL
AIM OF THE PROJECT	<i>The “Barocco Mineiro” expressed its highest pictorial form in the vault of the church of St. Francis of Assisi in Ouro Preto, considered as one of the “sete Maravilhas de Origem Portuguesa no Mundo”. The survey of the ceiling tested the accuracy of the latest technologies in metric data acquisition through three-dimensional photogrammetry. The 3D model has been the necessary base to obtain some scientific considerations about the translation of the rules of European Quadraturismo into Portuguese colonies in the late XVIII century.</i>

The foundation of the urban area of Ouro Preto, the most important mining town and the ancient capital of Minas Gerais, began with the early exploration of gold deposits that started last decade of the seventeenth century. The mines were located along the two rivers that flow from the Serra do Espinhaço, and in the course of Tripui, rich

deposits of gold, formed the first settlement of the future city. Today Ouro Preto combines history, culture and religion with the largest collection of art of its region and was declared a World Heritage Site by UNESCO in 1980 for its colonial architecture and the numerous and unique baroque churches.



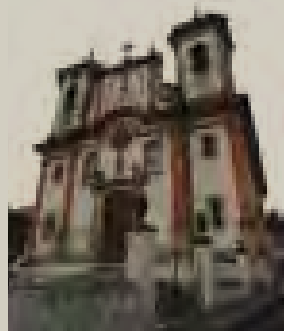


The urban fronts of the city are characterized by the bright colors of frames, doors and windows. The buildings are arranged in a line with the ground floor used as stock or commercial space and one or two residential overlying floors.



Lucio Costa: the evolution of traditional Brazilian house facade, from the seventeenth to the twentieth century.

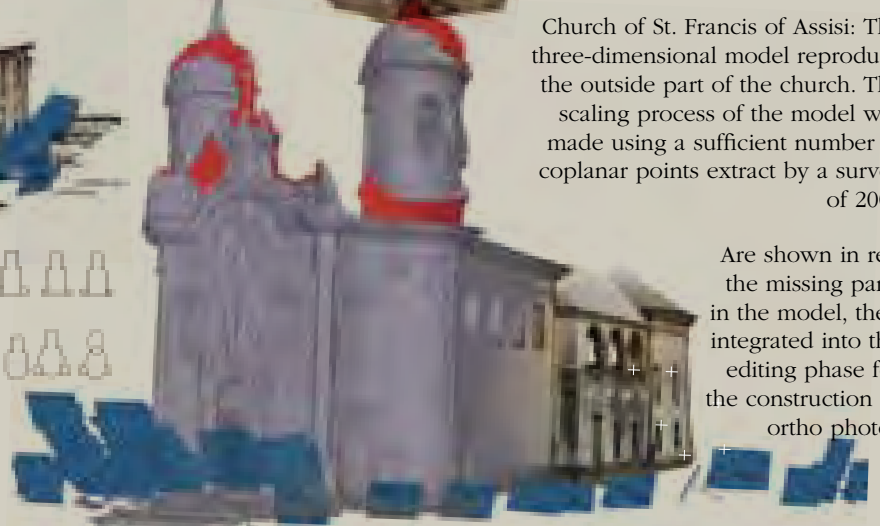
During the campaign in Ouro Preto was tested the 3D photogrammetry 3D as a technique of urban survey. The sample in question is a portion of about 25 meters of a urban front characterized by the presence of typical buildings in colonial architecture with two floors.



The mother church of Nossa Senhora da Conceição was built between 1726 and 1746 by Manuel Francisco Lisboa, the father of Antonio Francisco Lisboa, both buried in the church.



Drawings by Lucio Costa and Sylvio de Vasconcellos on the evolution of the facades and plans of the Baroque churches of Ouro Preto



Church of St. Francis of Assisi: The three-dimensional model reproduce the outside part of the church. The scaling process of the model was made using a sufficient number of coplanar points extract by a survey of 2008

Are shown in red the missing parts in the model, then integrated into the editing phase for the construction of ortho photos

Between 1730 and 1760, Ouro Preto lived the maximum phase of gold production and it was at this time that the first baroque churches were built. The materials, mainly of stone and wood, used in these buildings are more valuable and lasting than those used in the civil architecture. Starting from the original chapel, a model of simple church with modest size whose only function was to contain the image of the saint, a more complex structure of the church spread in the second half of XVIII century and consisted of the nave to which was added a second smaller body, the “capela mor”, the main chapel with the choir and the altar, the sacristy and, in some cases, the “capela posterior.” This kind of system is completely original but it certainly was founded on European art and architecture. The nave is a typical element introduced by the Coun-

ter-Reformation and the Jesuits, the main supporters of the evangelization of the New World, they came to America by importing their architectural models that seemed well suited to the new European colonies. The research project, started since the last year in collaboration with the Faculty of History of the Federal University of Minas Gerais, has as its aim the digital documentation of civil and religious architecture from the colonial period and the decorations, in particular the wooden vaults with paintings of false architectures. The studies discussed below are the result of some first surveys that took place on last November and a of parallel archival research. The European influence is clearly visible in the architecture of Minas Gerais, and especially in the religious buildings.

Church of San Francesco di Assisi, orthophoto of the fronts



The proof are the decorations of their doors that recall the German and French Rococo details and the decorated vaulted ceilings that, for the first time, represent illusionistic perspective, in Europe already spread from one century. The church of St. Francisco of Assisi is the most important building in the city, its facade, the sculptures of the portal and the pulpit, the side altars and the main chapel are the result of Antonio Francisco Lisboa's work, also called Aleijadinho, the main architect of Ouro Preto. The interior surprises the viewer for the painting of the Virgin on false wooden vault painted by Manuel da Costa Ataíde, now considered one of his masterpieces. For the decorative richness and color of the buildings in Brazil, also in relation to the availability of equipment and operators to carry out the surveys and investigations in situ, it was decided to make the expeditious photographic campaigns in order to produce three-dimensional textured models "image-based" from which we can derive the metric data.

Manuel da Costa Ataíde, Glorificação da Virgem, 1801-1812.

The ceiling of the church of St. Francis of Assisi has a wooden structure consisting of a main transverse warping and a secondary longitudinal who are nailed planks of varying sizes and with a thickness of about 4 cm. The illusionist oil painting is about the Glorification of Mary, at the center of the whole composition. Columns, pillars and arches in perspective link up the real architecture of the church to the principal topic of the painting.



Sylvio de Vasconcellos, study of the 'Golden ratio' in the facade of the church of St. Francisco of Assisi.



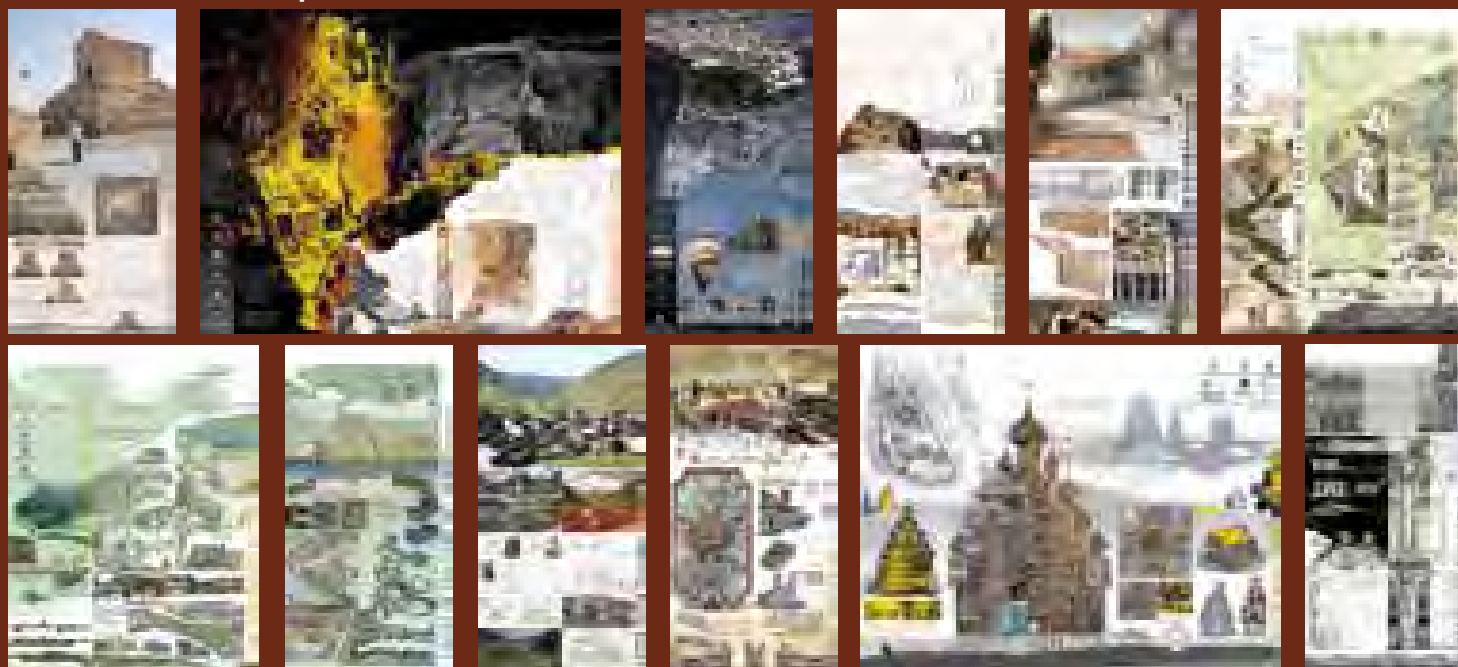
Exhibition

DOCUMENTATION AND DIGITAL SURVEY OF THE ARCHITECTURAL AND ARCHAEOLOGICAL HERITAGE PROTECTED BY UNESCO

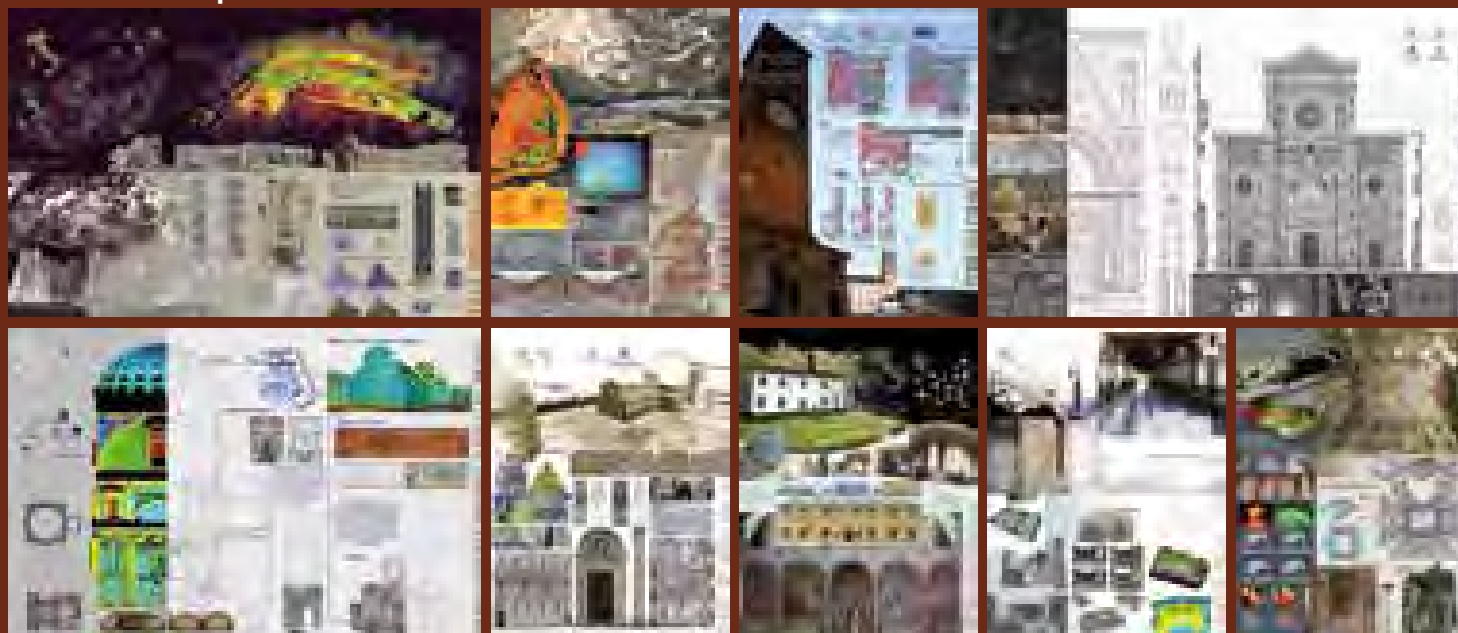
November 6-30, 2014, Florence, Italy

February 23-26, 2015, Tel-Aviv, Israel

International Experiences



National Experiences





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Credits

CREDITS OF THE BOOK:

The texts of the volume are written by STEFANO BERTOCCHI and SANDRO PARRINELLO, with the exception of the texts, on individual research projects, which show the initials of the following authors:

STEFANO BERTOCCHI wrote the texts for the following research projects:

Survey and Documentation of Masada Cultural Heritage, The Architecture of Crusader Castles in Petra, Research Experiences in the Old City of Acre, Laser scanning and survey in Pisa, Laser scanning for the monitoring of plastic deformation of Palazzo del Podestà in Mantua, Laser scanner survey of Medici Villas in Tuscany, Survey and 3D database of Michelangelo's architectures in Florence, Survey and documentation of Pitti Palace in Florence, Survey methodologies for the front of the Ekaterina Palace in Pushkin, The 3D survey of baroque church and architecture in Ouropreto.

SANDRO PARRINELLO wrote the texts for the following research projects:

Digital Survey for the tomb of Ciro the Great in Pasargadae, Study of transformations in the villages of Upper Svaneti, The external facades of the Florence Cathedral, Experiences of Digital Survey in the Uffizi complex, The survey of the Morro San Pedro de la Roca of Santiago de Cuba, The survey of the fortresses of Havana, The survey of the fortresses of San Juan in Porto Rico, The survey of the fortresses of Portobello, The survey of the fortresses of San Lorenzo el Real del Chagres, The survey of the Pogost Complex in the Kizhi Island.

Introduction of Hadrian's Villa archaeological site, text on page 67 and 69, were signed by: (B.A.) = BENEDETTA ADEMBRI, Responsible for the park of Villa Adriana, Superintendence of Archaeological Heritage of Lazio.

3D Models for Archaeology, text on page 70 and 72, were signed by: (F.F.) = FILIPPO FANTINI, University of Bologna.

Introduction of The survey of Villa del Casale, Piazza Armerina, Sicily, text on page 77, and the *restoration work*, text on page 80, were signed by: (R.B.) = ROBERTA BIANCHINI, Cooperativa Archeologia.

Survey Activity of The survey of Villa del Casale, Piazza Armerina, Sicily, text on page 78 and 79, was signed by: (L. C.) = LEONARDO CHIECHI, DigitArca.

Documentation for Restoration of the Nativity Church in Bethlehem, text on pages 83-86, were signed by: (G. P.) = GIAMMARCO PIACENTI, Centro Restauri Piacenti.

Introduction, The garden and The villa of Medici Villas in Tuscany, text on page 134, 135, 136, were signed by: (A.G.) = ALESSANDRA GRIFFO, Superintendence for Architectural, Landscape, Historical, Artistic Anthropological Heritage for the provinces of Florence, Pistoia and Prato.

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Natural ventilation for the Survey and documentation of Pitti Palace in Florence, text on page 163, 164 and 165, were signed by: (G.M.) = GIOVANNI MINUTOLI, University of Florence.

Introduction in Survey and 3D database of Michelangelo's architectures in Florence, text on page 141, were signed by: (V.V.) = VINENZO VACCARO, Superintendence for Architectural, Landscape, Historical, Artistic Anthropological Heritage for the provinces of Florence, Pistoia and Prato.

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The images of the volume have all been developed within the Joint Laboratory "Landscape Survey and Design" except where indicated.

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The exhibition was curated by

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The display panels were made by

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The panels of the exhibition have been printed in the LIA laboratory DIDAlabs with the support of Modula Informatica

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CREDITS OF RESEARCH PROJECTS:

Are reported, following, the credits relating to individual research projects presented in this volume. For the size of individual working groups, the credits have been simplified explaining the main roles of the actors who took part in the organization of the activities of the architectural survey. There are also reported, in each project, the students who participated in thematic seminars.

DIGITAL SURVEY FOR THE TOMB OF CIRO THE GREAT IN PASARGADAE

SCIENTIFIC BOARD OF THE PROJECT:	STEFANO BERTOCCHI, SANDRO PARRINELLO
TECNICAL COORDINATOR OF THE PROJECT:	FRANCESCA PICCHIO
PARTICIPANTS TO THE SURVEY:	
UNIVERSITY OF FLORENCE:	PROF. STEFANO BERTOCCHI, ARCHITECT PH.D. STUDENT MATTEO PASQUINI, ARCHITECT PH.D. STUDENT FRANCESCA PICCHIO, STUDENT SAEED AMAN.
UNIVERSITY OF PAVIA:	PROF. SANDRO PARRINELLO.
PARTNERSHIP PUBLIC INSTITUTIONS:	UNIVERSITY OF FLORENCE, DEPARTMENT OF ARCHITECTURE UNIVERSITY OF PAVIA, DEPARTMENT OF CIVIL ENGINEERING AND ARCHITECTURE UNIVERSITY OF TEHRAN, SCHOOL OF ARCHITECTURE, FACULTY OF ARCHITECTURE, COLLEGE OF FINE ARTS

SURVEY AND DOCUMENTATION OF MASADA CULTURAL HERITAGE

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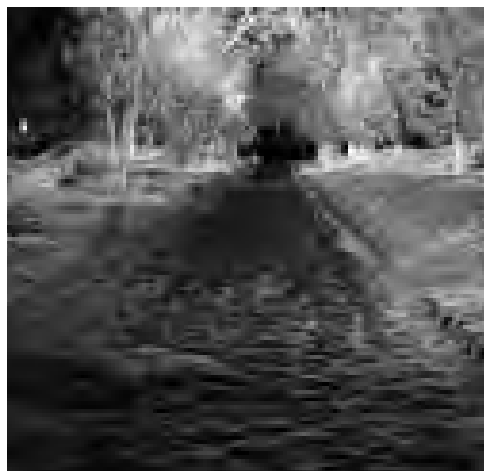
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