DIGITAL HERITAGE

INTERNATIONAL CONGRESS 2013
28 Oct - 1 Nov, Marseille, France

Proceedings of the

2013 Digital Heritage International Congress
(DigitalHeritage)

federating the
19th Int'l VSMM, 10th Eurographics GCH, & 2nd UNESCO Memory of the World Conferences,
plus special sessions from
CAA, Arqueologica 2.0, Space2Place, ICOMOS ICIP & CIPA, EU projects, et al.

Volume 2

Track 4 Policy & Standards
Track 5 Preservation
Track 6 Theory, Methodologies & Applications
Special Sessions

UNESCO
United Nations
Educational, Scientific and
Cultural Organization

VSMM

EG

IEEE
Advancing Technology
for Humanity

Table of Contents

Track 4 – Policy & Standards

Digital Heritage Policy & Societal Issues

Full Papers

Session−Policy Approaches & Case Studies

Short Papers

Session−Methodologies & Project

Posters

Track 5 - Preservation

Digital Preservation & Standards

Full Papers

Session−Metadata

Short Papers

Session−Preservation

Posters

Track 6 - Theory, methodologies and applications of Digital Heritage

Digital Heritage Solutions & Best Practices

Full Papers

Session 1−Reconstructing the Past

Session 2a−Documentation & Info Visualization

Session 2b−Applied Digitization & Reconstruction

Short Papers

Session 1−Museum & Digital Technology

Session 2−Applied Visualization & Reconstruction

Session 3−Architecture, Landscape: Documentation & Visualization

Session 4−Knowledge & Online Collections

Posters

Session 1

Session 2

Special Events

UNESCO Memory of the World

CAA Fall 2013 Symposium

Session: Sensing Archaelogical Landscpes & Sites

Session: Archaelogical Information Systems

Session: Communicating Archaelogy: Theory & Practice

ARQUEOLOGICA 5th Int'l Meeting

Session: New Tools for New Methods of Archaeological Research

Session: Documentia. Digital Documentation of Archaeological Heritage

ICOMOS ICIP Interpretation Panel

Space2Place Symposium

Museum & Technology

Special Sessions

Panels

Tutorials

Workshops

Bologna porticoes project

A 3D repository for WHL UNESCO nomination

Fabrizio I. Apollonio, Marco Gaiani, Federico Fallavollita, Massimo Ballabeni, Zheng Zun
Dipartimento di Architettura, Università di Bologna
Bologna, Italy
fabrizio.apollonio@unibo.it

Antonella Guidazzoli, Antonio Baglivo, Maria Chiara Liguori
CINECA
Casalecchio di Reno (BO), Italy
visitlab@cineca.it

Mauro Felicori, Luigi Virgolin
Economic Development and City Promotion Department
Bologna City Council
Bologna, Italy
luigi.virgolin@comune.bologna.it

Abstract— **The system of Bologna porticoes, included in 2006 in the Italian tentative list of World heritage sites of UNESCO, will undergo a definitive recognition of the nomination as part of the program of the current municipal council. The nomination is aimed at highlighting the portico, not only as a high-quality architectural work, which in the past centuries has become a distinctive feature of the town, but also in its social, community and anthropological meanings, as a meeting place, a protected space. The nomination project refers to different subjects and is divided into many levels of action. Among them we are going to develop a platform conceived for on-line accessing the wealth of data and resources related to the Bolognese porticoes system, such as historical, artistic, architectural resources, besides all those data regarding its actual management. The platform will perform the harvesting of several already existing databases, making the data available to citizens, tourists and scholars thanks to a graphic interface allowing a navigation in space and time. Therefore our system will facilitate the development of further cultural and promotional cross-medial applications, such as apps for mobile devices, augmented graphics and 3D architectural mapping events. Through social media tools, citizens will be invited not only to enjoy and share the proposed contents, but also to take an active stance in the project by uploading contents and comments. The core of our platform will consist of reality-based high quality 3D models usable and navigable within the system as main user interface. Uniform quality and consistency of our reality-based 3D digital models along the more than 40 km of porticoes was ensured by a controlled, low-cost process starting from photo-modeling techniques.**

Keywords —Cultural Heritage; Photo Modeling; 3D Models; Digital Color; Bologna;

I. INTRODUCTION

The Portico of San Luca and the system of porticoes of Bologna were included in 2006 in the Italian tentative list of World heritage sites of UNESCO and the definitive recognition of the nomination of Bologna as a UNESCO world heritage site is part of the program of the current municipal council.

The nomination is aimed at highlighting the portico, not only as a high-quality architectural work, which in the past centuries has become a distinctive feature of the town, but also in its social, community and anthropological meanings, as a meeting place, a protected space: 'a common good'. The nomination dossier will have to stress the worldwide uniqueness of the porticoes of Bologna as cultural, material and immaterial heritage. For these reasons, the nomination project refers to different subjects and is divided into many levels of action, among which the preparation of the nomination dossier for the historical-scientific aspects. Other levels of action include the editing of the Management Plan, which will have to regulate the preservation, valorization, promotion and monitoring of the heritage, in order to emphasize the role of the porticoes and to manage them in an innovative way, considering them in their cultural, social and economic dimension. In this paper we present the platform conceived for on-line accessing the wealth of data and resources related to the Bolognese system porticoes. Secondly we presents the core of our platform, that will consist in a collection of reality-based 3D models with level of detail at the architectural scale and semantically enriched. Three perspectives are here integrated as a common methodological approach: the Municipality of Bologna, the CINECA and the Architecture Department of Bologna University (DA) are cooperating, according to their different roles and competences, to develop the whole system. Among the stakeholders, DA is devoted to the creation of 3D models, working in strict cooperation with Bologna City Council SIT department in order to integrate the 3D models inside their City Council database system. Another content manager is the Open Data framework of the Municipality of Bologna, already hosting 3D data related to the history of the city (http://dati.comune.bologna.it/3d). Finally CINECA (www.cineca.it) is developing the platform.

II. RELATED WORK

Before the creation of the platform, a survey work has been carried out in order to ensure the use of the best tools to pursue the goal. The platform design requires a software architecture able to grant the subsequent development of cross-media applications, together with the harvesting of different contents from external repositories, making them available into the various access interfaces to the platform. Each content is referenced by time and space. The aim of the platform is to be independent from these different contents.

This type of architecture has been tested in a previous project, called PARSJAD (a cross border cooperation, between Italy and Slovenia, focused on the common archaeological heritage of the Northern Adriatic coast), aiming at visualizing data pertaining to a multimedia cultural database on a geographical interface [1]. Both PARSJAD and the Porticoes UNESCO Project have the same requirements, which led to the adoption of a multi-tier architecture: a three-tier one [2]. Another key issue is the use of WebGIS for the visualization of the cultural heritage contents through a geographical platform for the Web. The Porticoes project relies on different kinds of data, such as GIS data. Therefore, after having studied the state of the art analysis performed in the work [3], related to 3D GIS, 3D Web and 3D WebGIS, it has been decided to use a Web Map Service (WMS) in order to visualize an updated map of Bologna developed and released by SIT (Territorial Information System) of Bologna Council. Alternatively, users will be able to visualize and interact with another map, chosen among the most popular ones available on the web (e.g. Google Map, Bing Map, Openstreetmap, etc).

To ensure a trans-media and cross-media use of the platform, it is mandatory to evaluate a conceptual data model which should be built upon a unique data schema, useful to handle both several types of information (text, data, pictures, 3D models, etc.) and behavioral rules of the platform.

For this purpose, it was firstly taken into consideration CityGML (http://www.citygml.org/) as a prospective data model. CityGML is a common information model with XML-based encoding for the representation, storage, and exchange of 3D virtual city and landscape models. A CityGML model allows to represent georeferenced urban spatial data consisting of, among others, digital terrain models, buildings, land use vegetation and roads [4, 5]. CityGML has two aspects: on one hand, CityGML is widely supported on several platforms (such as BS Contact Geo, CityServer3D, TerrainView, GEORES, and so on) and many programs can be interfaced with it. On the other hand, it is more difficult to add further features to CityGML data model, albeit the creation of another XML Schema document, which should work in parallel.

For this reason, CityGML was discarded for the present project in favor of the development of a specific schema with the required features. Therefore, in order to meet the requirements of the Porticoes project, a XML Schema (http://www.w3.org/XML/Schema) has been designed to create an appropriate data model and to define specific rules for the platform. This latter activity is useful for two purposes: for the metadata and the metainformation, which enables us to visualize the contents defining specific rules, and also for the management of harvested data by heterogeneous repositories.

Inherent to the management and visualization of 3D models through the platform [6], the work carried out by Walczak, Flotynski and Dalkowski regarding a multi-platform 3D virtual museum exhibition, has been particularly inspiring for the design of the platform architecture. They used Flex-VR as the intermediate data model [7]. This is an exhaustive study that allows the visualization of 3D contents by any device with different operating systems by adopting a cooperative approach between an intermediate data model and X3D (http://www.web3d.org/x3d/), AWD (code.google.com/p/awd/) and PDF3D (http://www.pdf3d.com/). X3D is a standard ISO/IEC 19775-1 describing a scene graph using XML and, thanks to the framework X3DOM (http://www.x3dom.org), it is possible to make the content of a X3D document via Web available without any plug-in. Since X3DOM works only with WebGL browsers, in case of other browsers, it is still possible to visualize 3D contents by using AWD, with Adobe Flash Player, or PDF3D format, with Adobe Reader. The present project, instead of FlexVR, uses the XML schema described above to cooperate with X3D, AWD and PDF3D.

III. Dynamic repository of 3D models: Structure and organization of the data system

The platform of 'Bologna Porticoes UNESCO Project' foresees the visualization of knowledge about Porticoes, seen as cultural and virtual heritage contents through a web mapping system. Data are harvested by heterogeneous systems which communicate with the platform by means of specific protocols. Data will be referenced by taking into account space and time coordinates and users should be able to enter new contents and enrich the already available data. Therefore, the different user interfaces for the platform will be characterized by a friendly time bar and labels classified by categories (such as history, history of art, cultural and social events, and so on). The software architecture will ensure data harvesting from the repositories and the presentation of data itself by means of a space-time interface available on Web and mobile devices (particularly iOS and Android systems). In order to achieve the above-mentioned goal, it is necessary to set a software infrastructure divided into different modules: each one should be able to work independently, to share and communicate data among them, by means of a multi-tier architecture approach.

The three-tier architecture adopted consists of a data tier, a logic or intermediate tier and a presentation one: the task of the data tier is to acquire data by harvesting them from different databases; the logic tier handles data, creating a metadata layer in order to perform the visualization of the contents on different kind of out-puts (presentation tier).

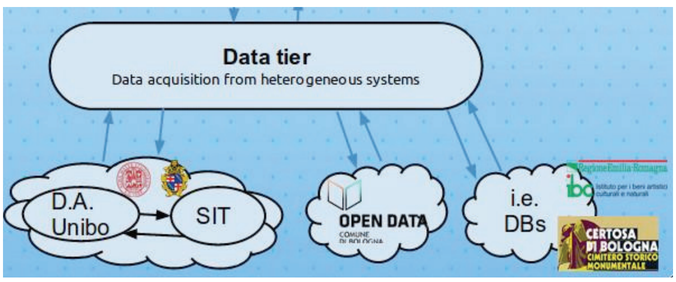

Fig. 1 Data tier, data acquisition from heterogeneous systems.

The data tier is a module whose task is the collection of data by several autonomous independent repositories by means of a specific communication protocol. Among the data available there will be also 3D models, referenced as well in space and time. Each repository communicates with the 'Bologna Porticoes UNESCO' platform by an effective data model, defined according to the native communication protocols of each database. The logic tier is designed to guarantee and manage the cross-mediality of the future applications. It is handled through a specific conceptual data model, which creates metadata according to the *ad hoc* schema model. This step is preliminary to the presentation tier.

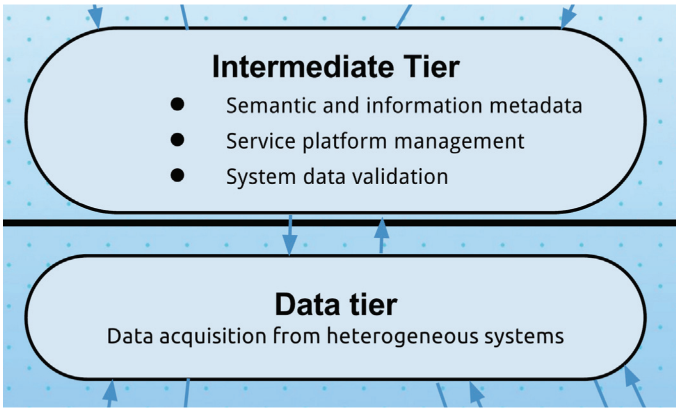

Fig. 2 Relationship between data tier and logic tier.

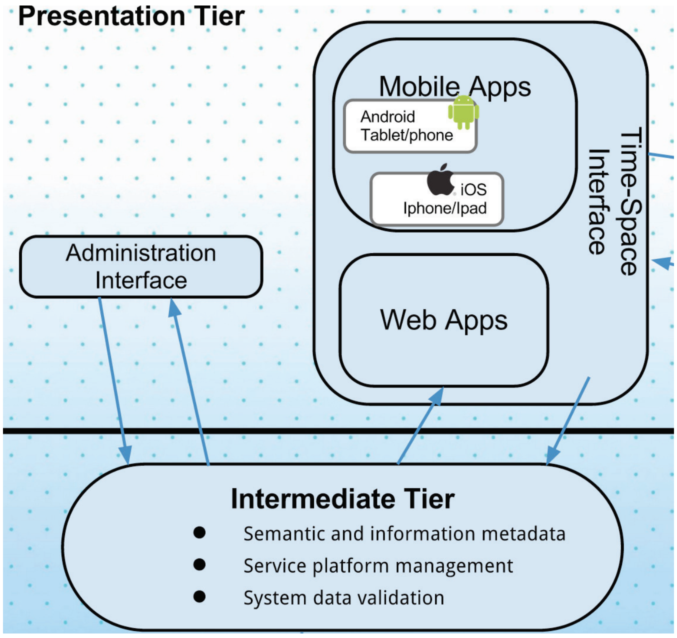

Fig. 3 Relationship between logic tier and presentation tier.

The presentation tier defines the graphics interfaces available to end users. Three different graphics interfaces will be developed: the first one is for web applications, the second one is related to mobile devices and the last one is the interface for administrators, allowing the platform management and the validation of data proposed by citizens.

Final users will access the platform by an authentication provided by the most popular social media (such as, Facebook, Foursquare, Instagram, Twitter, etc.). As follows, authentication allows to visualize the public part of the platform. Specific hashtags will be defined in favor of the disseminations of the records related to Bologna porticoes. Moreover, thanks to the Instagram public records it is possible to visualize them with hashtags and geolocation coordinates.

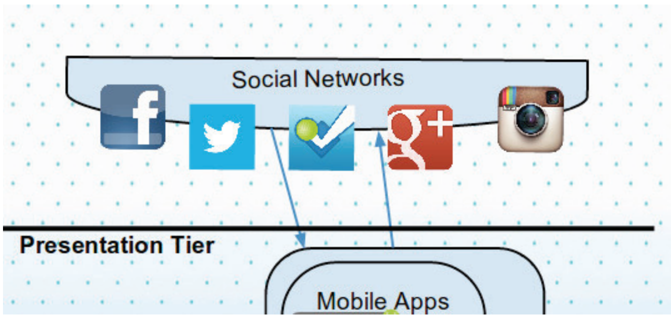

Fig. 4 Access to the presentation tier through social media.

This platform will offer fundamental support in involving citizens, and enabling them to develop personalized applications (such as games, social events, multimedia products, etc.), for a successful and sustainable UNESCO candidacy.

IV. A COLLECTION OF REALITY-BASED 3D MODELS

A. Reality-based 3D digital models.

In order to highlight the porticoes urban system and to ensure the immediate display of its unique characteristics a key point of our project was the construction of a collection of 3D models. A main difficulty in the process stems from the impossibility of building 3D reality-based models of this large Architectural Heritage (AH) with a single campaign of acquisitions and restitutions: different artifacts are modeled by different operators working in different places at different times and often using different methods or different technologies to produce multifaceted models.

In this scenario, there is a need for consistent, unambiguous technical specifications, tools, methodologies and operative techniques. We developed easy, low-cost and rapid procedures able to ensure high geometrical and visual accuracy while being accessible to non specialized users and unskilled operators.

Our pipeline is completely camera-based. In this way the process of data acquisition consist just in taking many photos with low-cost digital SLR cameras. Color acquisition and visualization process is quite integrated with shape capture process, based on computer vision techniques (e.g. structure from motion, SFM). Overall, the method does not require specific technical knowledge and is therefore relatively easy to use and it can be used repeatedly over large portions of the city. Specific attention is given to the procedures used in image acquisition, color management and color mapping to a 3D model.

Our workflow, methods, standards and operational best practices are completely device-independent; consequently, our choice of instrumentation, within certain limits, does not fundamentally affect the results. Many cameras (i.e. Canon

40D, Nikon D 3100, etc.) were used in the acquisition system for our experiment and different other devices, but the results demonstrate the robustness of the developed system.

B. Low-cost 3D modelling

The fast technical advances in the field of photo modelling over the last few years have led to the introduction and availability of many freeware, on-line, and commercial software (e.g. Autodesk 123D Catch, ARC3D, VisualSFM, Acute 3D and Pix4D) that can perform a 3D reconstruction from a collection of images: these images may have been taken by different people at different times or with different cameras, but can be recognised and merged to produce a model. In these software matching algorithms (e.g., SIFT [8]) allows to identify accurate correspondences. These correspondences are then used in SFM algorithms to estimate the precise camera pose, which are finally used as input into multi-view-stereo (MVS) methods that produce dense 3D models with a comparable accuracy to laser scanners [9]. MVS algorithms simultaneously correlate measurements from multiple images to derive 3D surface information.

Recent studies [10] [11] have shown that reliability and repeatability issues are encountered when SFM methods are used for complex and long sequences; however, the performance in terms of the computed object coordinates is often surprisingly positive.

We verified also that the accuracy of these software was at least that required by our case study (common architecture, not major architecture) with a series of preliminary tests in which we compared data from SFM and data from laser scanner ToF. Test results and literature led us to use photomodeling techniques allowing a simple, quick, low cost procedure ready to use by non-expert operators. Besides with dense 3D reconstruction from images software it is possible to exploit the power of cloud computing in order to carry out a semi-automatic data processing. A last choice of our work was to use free software to be sure that at the end of the work our data will be reused and integrated over the time.

The final pipeline is based on Visual SFM [12] to generate sparse reconstruction, Michal Jancosek's CMP-MVS [13] to generate dense reconstruction, Michael Kazhdan and Hugues Hoppe screened Poisson for surface reconstruction [14] and MeshLab from Visual Computing Lab of ISTI – CNR (http://meshlab.sourceforge.net/) for mesh editing. This solution, though comprising several software, is more adaptable, manageable and accurate [15] of the pipeline based on a single software.

VisualSFM provide interfaces to run PMVS/CMVS tool [16, 17] and CMP-MVS. VisualSFM uses algorithms that are also used in other SFM software from feature correspondence to sparse bundle adjustment and provides an interface to run dense points reconstruction. This package can reconstruct large scenes from multi-views and users can set parameters and receive feedback (as graphs and reports) at each stage; the package has the following functionalities: a) feature detection, b) feature matching, c) sparse 3D reconstruction, d) dense 3D reconstruction, e) coordinate transformation, f) mesh generation. VisualSFM, owing to its SIFT algorithm and parallel bundle adjustment [18], is suitable for reconstructing large scale 3D scene with complexity of space and illumination. Similar algorithm have been successfully applied to large scenes from unstructured web-images [19, 20, 21], which vary in camera set, zoom level, image size, and illumination. Web-based 3D reconstruction solutions such as 123D Catch and ARC3D well perform when the viewpoints are well organized - target encircled by cameras and great overlap in each pair. When the images vary in content and illumination (figure 5, 6), some of them tend to be not registered. Therefore, such web-based solutions fulfil the reconstruction of a statue or an isolated building, but they are not capable of modelling a room, a piazza or a piece of portico. An advantage of Visual SFM is to match only adjacent images with optional numbers instead of matching all pairwise. According to our test, around 1200 images (3456 pixel* 2304pixel) could be matched on a computer with a 4GB GPU.

From an operative point of view limits and appropriate use of the software are well described from Furukawa: "The clustering formulation is designed to satisfy the following three constraints: (1) redundant images are excluded from the clusters (compactness), (2) each cluster is small enough for an MVS reconstruction (size constraint); and (3) MVS reconstructions from these clusters result in minimal loss of content and detail compared to that obtainable by processing the full image set (coverage)." [17]

MVS approaches were developed for consumer cameras and cannot provide resolution as high as above 10 Mp, which modern cameras can readily provide. Instead, MVS approaches use moderate sized images of 1-4 Mp with a small capture space that can be used with visual hull constraints and volumetric optimisation algorithms. VSFM can scale up to larger images of 2-6 Mp using local plane sweeping strategies, which tend to be very slow when applied to larger images. While there are algorithms that can operate on higher resolution images [22], there are no algorithms for whole images [23]. This limited resolution, coupled with Bayer pattern sensor demosaicking from a single matrix of red, green, and blue pixels, can severely limit the colour accuracy.

Fig. 5 The same photo set are registered in Visual SFM.

In our case study following factors influence the results:

a) images properties: image with more pixel gives rise to more points, but also increases the processing time and risk of crash. Colour-calibrated images are shown to better contribute to the feature correspondence than non-calibrated images.

b) Camera parameter: SFM techniques estimates focal length from EXIF or use self-calibration techniques, but setting calibration parameters or using undistorted images would improve the level of accuracy.

Poisson surface reconstruction creates watertight surfaces from oriented point sets. The work [14], implemented in a simple command line software, extend the technique to explicitly incorporate the points as interpolation constraints. The extension can be interpreted as a generalization of the underlying mathematical framework to a screened Poisson equation. In contrast to other image and geometry processing techniques, the screening term is defined over a sparse set of points rather than over the full domain. The results shown by the authors highly overcome previous solutions.

C. Colour acquisition and management

The last step of our pipeline is reflectance mapping. Cause that the AH surface is essentially diffuse, the bidirectional reflectance distribution function (BRDF) does not need to be modelled to faithfully reproduce the original artefact. Also the colour fidelity for AH do not need to be highly accurate as in paintings, but we try to get a perceived fidelity. The final result of our process is then simply an 8-bit depth RGB colour map that can efficiently capture the diffuse reflectance, applied as texture map to our mesh.

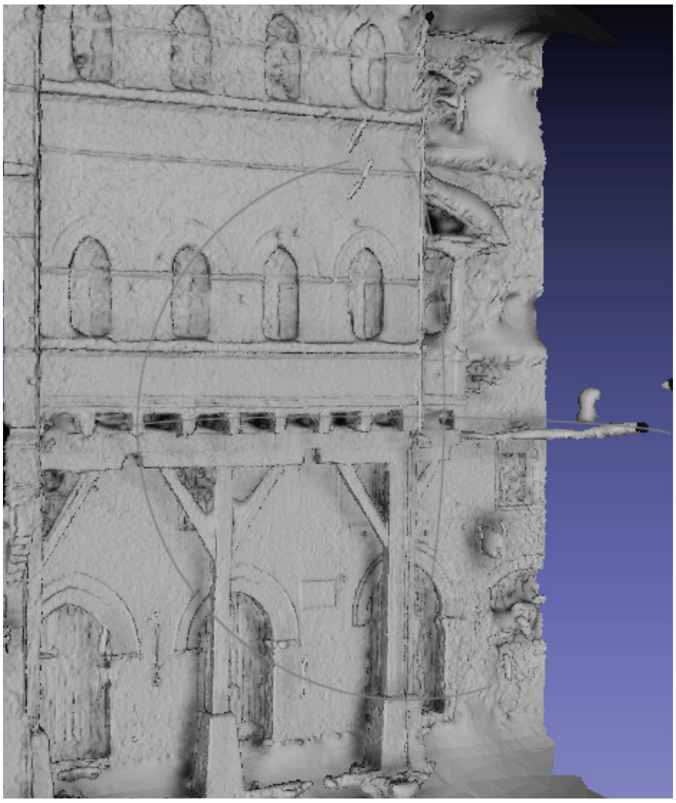

Fig. 6 The mesh of a portion of porticoes from our process.

We could project colour onto generated mesh from images that have been registered during sparse reconstruction. As large amount of images might lead to inaccuracy and long processing time, a small number of radiometrically well-calibrated photos - ensuring that the mesh was fully covered - were used for texture mapping by parameterizing the mesh surface [24]. This algorithm is well performed in dealing with complicated geometry such as portico. Unresolved issues in this context involve camera colour calibration, colour management, perceived colour visualisation at runtime inside the rendering engine (i.e., OpenGL graphics) and the variations that arise from the use of various cameras by different working groups, which can further affect many photo-consistency-based reconstruction algorithms [25].

Standard methods were used to ensure colour consistency in the acquisition and visualisation procedures. These includes a physical reference chart acquired under standard conditions, a reference colour space with ideal data values for the chart, a way of relating or converting the device colour space to the reference colour space and a way of measuring and displaying errors in the device's rendition of the reference chart.

The first step in colour management was to choose a correct colour space. The sRGB IEC 61966-2-1 conversely is an excellent solution, because it is a rendered space based on the features of the LCD reference monitor that is consistent from data capture to visualisation by different monitors or video-projectors, and is also implemented in the OpenGL libraries, which our rendering software is based on. We chose the AdobeRGB as working colour space, and we compressed the images in the sRGB colour space at the end of the pipeline. Using the Adobe RGB color space the reference chart image was neutral-balanced and properly exposed for the gamma of the reference data set; the ColorCheck reference data color space and target standard space was the same.

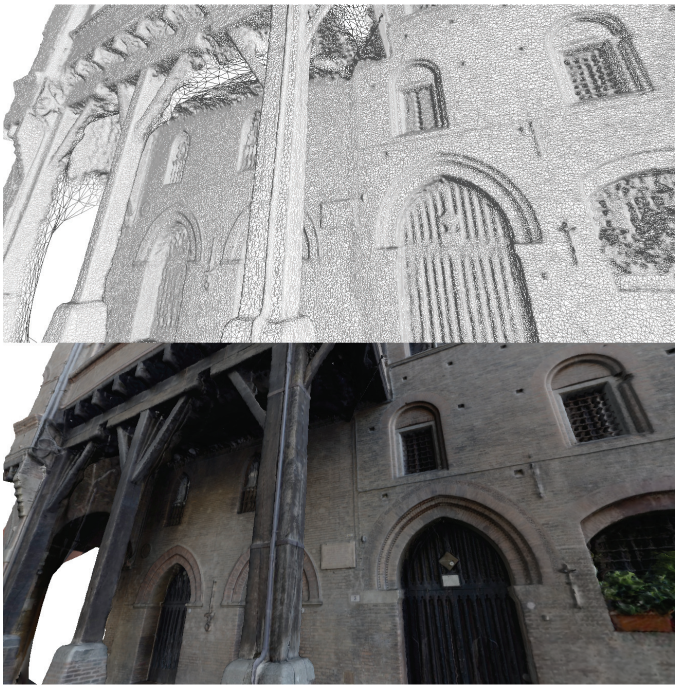

Fig. 7 Comparison between textured and untextured mesh from our process.

Reference ColorChecker chart patch values in Adobe RGB colour space are derived from Denny Pascale measurements [26]. Colour fidelity was ensured by performing a white balance against a series of Gretag Macbeth Color Chart using a fixed approach in two steps. In the first step, we used ProfileMaker 5.0 Pro to create an ICC profile that was assigned together with the ProPhotoRGB colour space to the RAW image. In second step, Adobe Photoshop Camera Raw tools were used to apply the ACR calibration scripts v. 4.3.1 (www.fors.net/chromoholics/) and the colour correction settings: however, the improvements were limited and perceptually negligible compared to the high cost in terms of the time and complexity of the process.

The colour accuracy was computed in terms of the mean camera chroma relative to the mean ideal chroma in the CIE colour metric (ΔE*ab) along with the white balance error; the noise level for the R, G, B and Y channels was assessed by evaluating the mean value of the average count level and the corresponding standard deviation for the grey level patches in the reference chart. The exposure error in the f-stops was also evaluated. Imatest Studio software suite version 3.8 (http://www.imatest.com/home) was used to evaluate the quality of the workflow and the master images. This step is based on the fact that two shots cannot be taken in the same frame (i.e., shots with and without the ColorChecker); however, we developed a protocol to use the same calibration for groups of images with the same features (e.g. orientation, exposure, and framed surfaces).

Fig. 8 Upper image: Gretag ColorChecker picture setup with and without a target; lower image, left: mean camera chroma relative to the mean ideal chroma in the CIE colour metric (ΔE*ab) for the colour balanced image; lower image, right: colour analysis for the same colour balanced image.

Thus, each group of photos (typically consisting of 200-300 images) used to model a building corresponded to no more than 4-5 different profiles, thereby maintaining consistency in the process and the results.

D. *Semantic structure*

3D models were conceived with the purpose to uniquely identify the buildings/artefacts and their related resources (images, 3D models, text, etc.) as elements connected with the 3D geometry. This requirement was met by constraining the final model to allow a semantic reading of the real object and the design intents throughout the interpretation of the shapes described by the model itself. Our approach used semantic modelling for descriptors as common denominator between heterogeneous information, possible representations of the building, and parametric modelling for data modelled from scratch, existing drawings or photos. Main step of our modelling pipeline was then semantic structuring of data.

The topological information is a major issue in the 3D model construction since it describes the spatial relationships between geo-objects and the capability of the models to be used into a 3D GIS. On the other hand, 3D models are an excellent mean for understanding architecture, describable as a collection of structured objects. The availability of 3D semantic models organized as cognitive systems meet the requirement to have a topological control on the advanced model which, in turn, enables a semantic approach to classic problem of creating models at different levels of detail, ensuring the appropriate level of accuracy. An architectural knowledge system, thanks to the similarity and homology between the architectural buildings and their 3D digital representation, is thus able to describe a series of structured objects using a specific architectural lexicon, similarly to what did in the structure and organization of Andrea Palladio treatise *I quattro libri dell'architettura* (Venice, 1570). Finally a semantic structure allows to manage efficiently metadata linked to the 3D models themselves, and with them the ability to view and represent data relating to the uncertainty reconstructive, to the level of accuracy guaranteed, as well as to control the various versions of the models and facilitate the comparative analysis between the parties or sets of architectural works.

Our semantic structure follows the classification method [27] where the architectural space is subdivided according to their level of 'abstraction' (clustering, topological and metric). Then the component parts were reassembled using a 3D extension of the 'put-together' method reported by Stiny and Mitchell [28] and adopting a 'shape grammars' that uses a pre-established set of tree-shaped formal rules which indicate a clear purpose and an evident structure. Further development used in our semantic technique are based on [29], [30], [31], [32], [33].

De Luca et al. [29] presented a methodological approach to the semantic description of architectural elements based on theoretical reflections and on research experiences. Sass [30] illustrated a method in which the rules for a shape grammar demonstrate the need for additional information and illustration for rule building. De Luca, furthermore, in a later work [32], aimed to identify the potential of structuring heterogeneous information within semantically enriched 3D models of heritage buildings according to multiple contexts: the documentation of the state of conservation, the indexation and retrieval of iconographic sources, the analysis and representation of spatio-temporal changes. Apollonio et al. [33] focused on the quality assessment procedures adopted to ensure consistency and reliability of data throughout the whole 3D models acquisition and pipeline creation, as well as on the particular semantic reality-based structure adopted to develop an information system into a knowledge one, using 3D models as archaeological cognitive systems and developing them as a collection of structured objects, identified through a precise terminology that allows to easily extend the concept of 2D GIS to 3D GIS.

Fig. 9 A colour balanced 3D model.

Our method is described mainly in [33] and deals with the scheme developed in [30], referring to the real built object, identifying, highlighting and discussing not only the scheme but also the constructive rules. The adopted 'shape-grammar' uses a pre-established set of tree-shaped formal rules, which specify a clear purpose and an evident structure. This structure can be extended if necessary over several hierarchical levels and allows us to manage, even in the stages of editing, successive models in a consistent manner, giving the possibility to obtain semantic models ready-to-use as a knowledge system. Therefore, our approach can identify, highlight and discuss not only the scheme but also the constructive rules. In addition, our method deals with a wider set of objects that can range from a simple brick or bas-relief to a whole building, and is not limited to architectural objects. The method requirements consist of the following:

1) naming each part;

2) identifying the number of elements corresponding to the definition of each individual part;

3) verifying the element and class of item naming;

4) measuring volumes underlying 3D surfaces obtained from data capture definition.

Unfortunately, it was impossible to automate the process of semantic model creation and naming for all acquired 3D models because the variants exceed the recurrences and architectural expertise is required. Therefore, to facilitate operation and to generate a robust 3D database we developed:

- an unambiguous method to segment the whole 3D model;
- an evidence-based technique for naming the parts that are well-integrated during the segmentation phase;
- a clear and simple list of reference cases and related solutions identified with the help of experienced architectural historians.

The segmentation process is performed using commercial software (e.g. Autodesk Maya) semi-automatically at two different levels starting from the reality-based model delimited by an urban block, that is our original 3D model:

1. urban level: each building is detected, segmented and bounded;

2. single building level: each part is detected, segmented and bounded.

Links between the 3D model parts and heterogeneous data are established after the semantic segmentation. CINECA is developing an 'ad hoc' interface starting from ViSMan software experience [34].

V. CONCLUSIONS

In this paper we presented some advance of Bologna Porticoes project , part of a larger project aimed to declare the arcades of Bologna as a UNESCO WHL.

For the project, CINECA is going to develop a platform conceived for on-line accessing the wealth of data and resources related to the Bolognese porticoes system, such as historical, artistic, architectural resources, besides all those data regarding its actual management. The platform will perform the harvesting of several already existing databases, making the data available to citizens and scholars thanks to a graphic interface allowing a navigation in space and time.

A significant section of the platform will visualize the 3D models developed at Department of Architecture of University of Bologna, models that will facilitate the development of further cultural and promotional cross-medial applications, such as app for mobile devices, games, augmented reality and augmented graphics and 3D architectural mapping events. Through social media tools, citizens will be invited not only to enjoy and share the proposed contents, but also to take an active stance in the project by uploading contents and comments.

We developed a process to have a wide collection of models at the architectural scale but regarding an urban extension. We report on the processes and techniques used, emphasising colour-related and shape acquisition issues. A method is developed to obtain photo-realistic 3D models by projecting digital images onto the geometry of the 3D digital models using low-cost technologies (e.g. photography) from non-specialised users and unskilled operators, typically AH architects. The acquired images are also used to generate the geometry of the 3D models using computer vision techniques. The process of acquisition of the images to get the finished 3D model is therefore unique and the process for acquiring and visualizing the colour is fully integrated within the process of shape capture. Overall, the method does not require specific technical knowledge and is therefore relatively easy to use and it can be used repeatedly over large portions of the city. Specific attention is given in the description of the measurement procedures used in image acquisition, colour management and colour information mapping onto a 3D model. The final result of our process was a huge collection of high quality reality-based 3D models semantically organized and usable in different contexts: communication, dissemination, urban management.

Future work will focus on the usability of the platform and on increasing the modelling quality by unskilled/non-IT-expert operators.

REFERENCES

[1] A. Coralini, A. Guidazzoli, F. Lenzi, M. Spigarolo, A. Baglivo, M.C. Liguori, "A Google Cloud Approach to Implement a Graphical Data Access Interface Binding Heterogeneous Cultural Repositories", in M. Ioannides, D. Fritsch, R. Caffo, R. Davies, F. Remondino, J. Leisner (Eds.), EuroMed2012 - Cultural Heritage, Springer, 2012.

[2] W.W. Eckerson, "Three Tier Client/Server Architecture: Achieving Scalability, Performance and Efficency in Client Server Applications", in Open Information Systems 10, 1 (January 1995).

[3] E. Ippoliti, A. Moscati, A. Meschini, D. Rossi, L. De Luca, "Shedding Light on the City: Discovering, Appreciating and Sharing Cultural Heritage using 3D Visual Technology", in G. Guidi, A. C. Addison (Eds.), Proceedings of the VSMM 2012 Virtual Systems in the Information Society, 2-5 September, Milan, IEEE, 2012.

[4] I. Prieto, J.L. Izkara, F.J. Delgado, "From Point Cloud to Web 3D through CityGML", in G. Guidi, A. C. Addison (Eds.), Proceedings of the VSMM 2012 Virtual Systems in the Information Society, 2-5 September, Milan, IEEE, 2012.

[5] T. H. Kolbe, "Representing and exchanging 3D city models with CityGML", in J. Lee, S. Zlatanova (Eds.), 3D Geo-Information Sciences, Springer, 2009, pp. 15-31.

[6] W. Cellary, K. Walczak (Eds.), "Interactive 3D Multimedia Content: Models for Creation, Management, Search and Presentation", Springer, 2012.

[7] J. Flotynski, J. Dalkowski, K. Walczak, "Building multi-platform 3D virtual museum exhibitions with Flex-VR", in G. Guidi, A. C. Addison (Eds.), Proceedings of the VSMM 2012 Virtual Systems in the Information Society, 2-5 September, Milan, IEEE, 2012.

[8] D. Lowe, "Distinctive image features from scale-invariant keypoints", IJCV, Vol. 60, N. 2, 2004, pp. 91-110.

[9] S.M. Seitz, et al., "A comparison and evaluation of multi-view stereo reconstruction algorithms", CVPR Proceedings, Vol. 1, 2006, pp. 519-528.

[10] F. Remondino, et al., "Low-Cost and Open-Source Solutions for Automated Image Orientation - A Critical Overview", Euromed 2012 Proceedings, Springer, 2012, pp. 40-54.

[11] M. Dellepiane, N. Dell'Unto, M. Callieri, S. Lindgren, R. Scopigno, "Archeological excavation monitoring using dense stereo matching techniques", Journal of Cultural Heritage, Vol. 14, N. 3, 2013, pp. 201-210

[12] C. Wu, "Towards Linear-time Incremental Structure from Motion", 3DV 2013 Conference proceedings, in press.

[13] M. Jancosek, T. Pajdla, "Multi-View Reconstruction Preserving Weakly-Supported Surfaces", CVPR Proceedings, 2011, pp. 3121-3128.

[14] M. Kazhdan, H. Hoppe, "Screened Poisson surface reconstruction", ACM Trans. Graphics, 2013, in press..

[15] D.Abate, "3D Modeling of a Gravestone Exploiting Low Cost Range and Image Based Techniques", presentation at 3D Digital Documentation Summit, National Center for Preservation technology and Training, april 2013.

[16] Y. Furukawa, J. Ponce, "Accurate, Dense, and Robust Multi-View Stereopsis", IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 32, N. 8, August 2010, pp. 1362-1376.

[17] Y. Furukawa, et al., "Towards Internet-scale Multi-view Stereo", CVPR Proceedings, 2010, pp. 1434-1441.

[18] C. Wu, S. Agarwal, B. Curless, S.M. Seitz, "Multicore bundle adjustment", Computer Vision and Pattern Recognition (CVPR), 2011 IEEE Conference on, pp. 3057-3064.

[19] S. Agarwal, et al., "Building rome in a day", Computer Vision, 2009 IEEE 12th International Conference on., 2009.

[20] N. Snavely, S.M. Seitz, R. Szeliski, "Modeling the world from internet photo collections", International Journal of Computer Vision, Vol. 80, N. 2, 2008, pp. 189-210.

[21] N. Snavely, S.M. Seitz, R. Szeliski, "Photo tourism: exploring photo collections in 3D", ACM transactions on graphics (TOG), Vol. 25, N. 3, 2006, pp. 835-846.

[22] H. Vu, et al., "Towards high-resolution large-scale multi-view stereo", CVPR Proceedings, 2009, pp. 1430-1437.

[23] E. Tola, et al., "Efficient large-scale multi-view stereo for ultra high-resolution image sets", Machine Vision and Applications, Vol. 23, N. 5, 2012, pp. 903-920.

[24] N. Pietroni, Tarini M. and P. Cignoni, "Almost isometric mesh parameterization through abstract domains." Visualization and Computer Graphics, IEEE Transactions on 16.4 (2010): 621-635.

[25] Z. Xu, et al., "Radiance-based colour calibration for image-based modeling with multiple cameras", Science China Information Sciences, Vol. 55, N. 7, 2012, pp. 1509–1519.

[26] D. Pascale, "RGB coordinates of the Macbeth ColorChecker", 2006

[27] A. Tzonis, L. Oorschot, "Frames, Plans, Representation Concept dicta at Inleiding Programmatische en Functionele Analyse" Technical Report, Delft, University of Technology. 1987.

[28] G. Stiny, W. J. Mitchell, "The Palladian grammar, Environment and Planning B: Planning and Design", 5, 5–18. 1978.

[29] L. De Luca, M. Florenzano, P. Veron, "A generic formalism for the semantic modeling and representation of architectural elements" Visual Computer, 23, 2007, pp.181–205.

[30] L Sass, "A Palladian construction grammar—design reasoning with shape grammars and rapid prototyping" Environment and Planning B: Planning and Design, 34(1), 2007, pp.87 – 106.

[31] F. I. Apollonio, M. Gaiani, C. Corsi, S. Baldissini, "An Integrated 3D Geodatabase for Palladio's Work" In International Journal Of Architectural Computing, 8(2), 2010, pp.107 – 129.

[32] L. De Luca, "Methods, formalisms and tools for the semantic-based surveying and representation of architectural heritage", Applied Geomatics, 2011.

[33] F.I. Apollonio, M. Gaiani, B. Benedetti, "3D reality-based artefact models for the management of archaeological sites using 3D Gis: a framework starting from the case study of the Pompeii Archaeological area", Journal of Archaeological Science, 39, 2012, pp. 1271-1287.

[34] T. Diamanti, P. Diarte Blasco, A. Guidazzoli, M. Sebastián Lopez, E. Toffari, "VisMan: an Open-Source Visualization Framework for Virtual Reconstruction and Data imanagement in Archaeology", VAST, Eurographics Association, 2010, pp.47-53.

2013 Digital Heritage International Congress

(DigitalHeritage)

federating the
19th Int'l VSMM, 10th Eurographics GCH, & 2nd UNESCO Memory of the World Conferences,
plus special sessions from
CAA, Arqueológica 2.0, Space2Place, ICOMOS ICIP & CIPA, EU projects, et al.

Volume 2

28 Oct – 1 Nov 2013
Marseille, France

IEEE Catalog Number: CFP1308W-USB
ISBN: 978-1-4799-3169-9