

EVALUATION OF LASER SCANNER PERFORMANCE IN DOCUMENTATION OF HISTORICAL AND ARCHITECTURAL RUINS, A CASE STUDY IN KONYA

A.Gulec Korumaz^a, M.Korumaz^a, O.N.Dulgerler^a, L. Karasaka^b, F. Yıldız^b, M.Yakar^b

^a Selcuk University, Department of Architecture, 42003 Konya, Turkey
gulec.armagan@gmail.com, mkorumaz@gmail.com, dulgerler@selcuk.edu.tr

^b Selcuk University, Faculty of Engineering, Department of Geodesy and Photogrammetry, 42003 Konya, Turkey-
lutfiye@selcuk.edu.tr, fyildiz@selcuk.edu.tr, yakar@selcuk.edu.tr

Commission V

KEYWORDS: Laser Scanner, Documentation of Architectural Ruins, Archeological Ruins

ABSTRACT:

Our country is rich not only with historical monuments also with many archeological places which especially belong to Rome, Seljukian and Ottoman period and before. Many late period historical monuments demolished because of destructive effects of wars, natural disasters, neglect. Conventional methods are not sufficient and sometimes they don't give good results in documentation of historical ruins because of the fact that the building or monument is structurally deformed. It is precedence needed to get 3D datum for research and documentation of these kinds of historical ruins. It gets more difficult to measure and draw these kinds of remains because of their deformation in their basic geometry and materials with destructive effects of years. Documentation with laser scanner is needed to determine destruction dimension, deformation, structural analysis and material measurement. This 3D documentation gives sensitive results in decision making process, restoration and restitution projects. In this study, it will be emphasized the importance of documentation of historical ruins and some examples scanned with laser scanner will be given from Konya-Turkey as example.

1. INTRODUCTION

Thanks to development in technology and electronics, techniques and methodologies in the field of topography, survey and construction are leading significant innovations for collecting 3D data, representation, rendering, reconstruction and surveying. Besides 3D surface models could generate solid models, sections, virtual models, textured surfaces and videos which has great impact in specialized documentation.

Architectural representation has been significant way of describing, visualization, documenting and understanding the edifices, historical buildings, sites and ruins. Especially in analysis efforts, it becomes the only way to understand the cultural heritage. By the time, it has mainly focused on graphics and illustrations connected with realism. Parallel to them, analysis of raw documentary sources benefited from the development of various data management techniques.

It can be easily observed that architectural representation and architectural scientific analysis have been divided by computer techniques and disciplines. When researchers and practitioners in the field of architecture wanted to integrate documentation analysis and representation they would face a lack of appropriate solution. In many cases, 2D/3D graphics could be insufficient or cultural heritage could not localize with space position of it.

In this study example projects scanned by laser scanner will be displayed and laser scanner in documentation of cultural heritage will be evaluated and new innovations in documentation of cultural ruins will be emphasized with examples.

2. HERITAGE DOCUMENTATION

The development of technology and electronics has opened new possibilities in the field of survey, analysis, representation, information, decision and communication of Cultural Heritage. Achieving 3D model is easy for documentation and survey works and it is easily obtainable with high automation today. Integration of different survey methods in relation to the complexity and detail level seems the right way to get good results (Agnello F et al.) With the recent studies in the field of 3D Cultural Heritage, it is possible to generate reconstructed cultural objects, historic buildings and environments and to access by the user.

Architectural documentation is a complex process and it includes much information from other disciplines. Recording only the geometry of cultural heritage is insufficient because it is not only valuable parameter. A cultural heritage also has architectural, aesthetical, historical and social values which need to be recorded. In this context, photogrammetry has always been a technique providing large amount and accurate data, 3D and textured data, high resolution and detailed data with geo-reference and giving possibility to generate stereo-view data. In spite of these abilities, it sometime requires medium or high hardware and software. In contrast to some photogrammetric applications, cultural heritage documentation is more challenging and varying due to the object size or requirements. Here are the some problems,

- *the object is not accessible
- *the object is too large or too complicated
- *the object is in danger (environmental factors, disasters or earthquakes)

- *the object has only small part of its original
- *the environment of the object is too complicated or not suitable to take measure (Patias, P).

Other factor which should be taken into account is,

- *choosing appropriate technology
- *deciding appropriate procedures
- *deciding appropriate methodology

Common features of documentation stated by the international agreements are;

- recording of a vast amount of four dimensional (i.e. 3D plus time) multi-source, multi-format and multi-content information, with stated levels of accuracy and detail;
- digital inventories in 3D and, as far as available, dated historical images;
- management of the 4D information in a secure and rational way, making it available for sharing and distribution to other users; and
- visualization and presentation of the information in a user-friendly way, so that different kinds of users can actually retrieve the data and acquire useful information, using Internet and visualization techniques (Patias, P.).

Architectural and archeological photogrammetry and vision techniques can be classified in many ways and according to different parameters. In general documentation can be classified according to purpose for

- *analysis
- *conservation, restoration, reconstruction
- *archeology
- *small objects (artifacts)
- *historical quarters, urban settlements,
- *visualization

3. 3D HERITAGE

Actual technologies and methodologies for Cultural Heritage documentation allowing 3D realistic model with exact geometry and texture is used for many purposes like documentation, digital conservation, restoration, reconstruction, VR applications, storage data, information management, web sources etc. Despite all these possibilities, cultural heritage documentation has still some difficulties in practice about 3D like

- * cost of 3D
- *achieving to 3D models by everyone
- *storing large amount of data
- *integrating 3D model with other standard 2D models

However, the use of 3D models of heritage permits new analyses, surveys, studies and innovations in digital preservation. For his reason, 3D models should be effectively and more used due to these advantages (Remondino F. et al., 2009)

Today digital documentation and 3D modeling of cultural heritage should consist of large amount of dimensional information and resolution, management of 3D and 4D models for further applications, visualization and representation for the results, distributing information to other users, accessibility information through databases and sharing information for

different purposes like education, tourism. Each of these properties is not eligible for only unique technique; therefore in many documentation projects different techniques are combined.

3.1. Laser Scanners

In architectural documentation laser scans have also place in visually significant studies like urban studies, historic area, important building or any architectural ruin. For the large objects like historical quarters, sites and monuments, laser scanning is used with photogrammetric techniques. Subsequent processing of point clouds generate not only orthogonal projections also 3D mesh models, polygonal models, outlines, sections, 3D views, 3D textured models and 3D model videos (Caroti G et al.)

Thanks to its speed and accuracy terrestrial laser scanning has gained more significance as a measuring tool in the field of architectural and cultural heritage. Terrestrial laser scanners have many advantages in the field of architecture like:

- *speed
- *accuracy
- *capturing built environment
- *getting data in a quick and easy way
- *3D and 2D data

Laser scanning is especially good for complex surfaces, surface analysis and visualization. In contrast to these advantages, laser scanning has also some challenging. It is difficult to derive the line drawings in laser scanning. Besides, edges cannot be extracted sometimes. Another problem is –developing and changing by the time- is handling huge amount of data. In deformation monitoring laser scanner is not used a lot according to Van Genechten because of its relatively low single point accuracy. He mentions “The precision that can be achieved with modern mid-range laser scanners varies from 5 to 25mm. This accuracy depends on the laser type and the measuring principle used, but it is also influenced by the measurement conditions such as the temperature, the wind, the surface roughness and last but not least the surface inclination angles. This is approximately 1 order lower in magnitude compared to traditional surveying techniques such as total stations or contact sensors. However, the main benefit of laser scanners for deformation monitoring is the fact that no prior knowledge is required concerning critical zones”. Also according to Litchi 2002, in order to optimize the accuracy even further, multiple scans of the same object can be acquired sequentially, increasing the number of points and thus theoretically improving the standard deviation of a single point measurement (Van Genechten B et al. 2009)

3.2. Point Cloud for Heritage

3D modeling based on a point cloud issued from laser scanning has led many publications. Two kinds of methods can be distinguished to achieve this modeling

- *the modeling with automatic adjustment of simple geometrical shapes on the point cloud with mean square methods
- *the treatment of the point cloud for the mesh creation of complex shapes (Chevrier C et al.).

In the first method, databases of objects are memory cheap and shapes are simple. In the second method, databases are so

memory expensive which can be used only for sculptures and non geometrical shapes. So, techniques that combining several methods are the most appropriate for architectural purposes because of dealing with a wide range of data(Chevrier C).

In data acquisition and processing of large sites, large amount of data makes time consuming and difficult processing at high resolution. In contrast, processing at low resolution makes accuracy problems. Combining data at different resolution and viewpoints can affect the accuracy of the 3D model. Despite combining with different methods, some gaps and dark parts still be present in the model, some surface patches could be invisible. Other important thing is distance should be optimal for the site or object in order to get 3D entirely. Here, photograph taken from the same viewpoint is required and obtained with the texture mapping phase (Remondino F et al.,2009)

4. MEASURING ARCHITECTURAL RUINS

It is easier for an architectural heritage to transform it throughout the centuries when it has not been totally destroyed which also means that practitioners have chance to visualize it hypothetical. Architectural heritage has been exposed to many bad effects like bad use, neglect, natural disasters. As a result of these effects they lose their some parts and something related to their identity. Due to these effect causing losses, we have inherited some structures as ruins. In these cases, it is more difficult to start the valorization process and deep investigation in order to transmit the ruin to the future with its value and all special traces. Researcher should be very carefully here and carry on his investigation with patience and attention. To be able to restore architectural ruins, detailed surveying is required and for his all traces related to ruin becomes very significant and valuable.

Building ruins can be defined as the remains of human made structures which have fallen completely or partially due to lack of maintenance or some deliberate destruction. Natural disasters, human factors, wars, weather, bad use, neglecting and depopulation-population decline- are the most common reasons causing structures to become a ruin. Survey of these buildings requires varying surveys, evaluation of elevation consistency, evaluation of the structural layout, and the quantification of decay symptoms. In the survey process, uncertain building outline, collapse part of the structure, destroyed parts of the structure; presence of vegetation makes the survey and documentation difficult. It is risk to define uncertain shape so high resolution metric instruments like three dimensional techniques and high resolution cameras and photogrammetric techniques should be used. Furthermore the measurement accuracy of the acquisitions phase is preserved more or less unaltered in the final graphic results (Tucci G).

Scanning systems in data acquisition phase makes the time spent on site. Because it is mostly automatic and time saving, they are useful in ruined buildings where an unreliable part of the structure requires particular attention.

5. CASE STUDIES

5.1. Determination of Present Situation

In the past, statistical surveys were made and measured drawings of architectural and archeological ruins were prepared with traditional methods. In this study, to evaluate the usability

of Laser Scanner for street silhouette, only measurements taken with Laser Scanner were used. Ruins were scanned with 5 mm precision. Scanning of the ruins was executed by Optech's ILRIS-3D terrestrial laser scanner. Optech's ILRIS-3D Laser imaging system provides the means to reduce the time and cost significantly.

Features of the Laser Scanner:

- *High resolution and high accuracy
- *Highest dynamic range available on the market: from 3m to 1 km
- *Class I laser rating: completely eye safe
- *On-Board 6 megapixel digital camera and large format LCD viewfinder
- *Ruggedly designed for demanding field applications
- *Battery operated
- *No leveling, retro-reflectors or mirrors required
- *Compact and easy to use
- *Easily hand-carried and deployed by a single operator

Performance	
Dynamic scanning range	3 m-1,500 m to an 80% target 3 m-800 m to an 20% target 3 m- 350 m to an 4% target
Data sampling rate (actual measurement rate)	2,500 points per second
Beam divergence	0.00974°
Minimum spot step (X and Y axis)	0.00115°
Raw range accuracy*	7 mm @100m
Raw positional accuracy*	8mm@100m
Laser wavelength	1500 nm
Laser class (IEC 600825-1)	Class I **
Digital Camera	Integrated digital camera ;(CMOS sensor) optional external camera
Scanner field of view (ILRIS-3D)	40° x 40°

Table 1: ILRIS-3D features

5.2. Alaeddin Kosk Run-Konya

Alaeddin Kosk is remains of the palace belonging to the Seljuk sultan in Konya. The mansion was built by whom, although not as definitive information about the art historian, it is thought that it was built by II.Kılıçarslan (1155-1192). Later years, according to Evliya Çelebi palace was demolished by the earthquake and Alaeddin Keykubat repaired it. Therefore it is known by the name "Aleaddin Kosk" in Konya, considered to be a part of Seljuk Palace. Aleaddin Kosk in Konya and on Aleaddin Hill in the middle of rising mounds, called the surrounding walls of the Seljuk Period had been located on a bush. This concrete umbrella had been built in 1960's.

In order to document this ruin, ILRIS-3D terrestrial laser scanner was used. To get 3D images to 3D polygonal model, PolyWorks Version 10.0 InnovMetric software was used. Firstly, the binary data provided by Optech ILRIS-3D were

parsed using Optech Parser 4.2.7.2. to get point cloud in .IXF format processed by Innovmetric PolyWorks 10.0. Secondly the translated images were imported into PloyWorks InnovMetric software and then merged into one polygonal model. Scanning process completed from several edges. To get 3D model of the ruin completely 4 building's roofs and balconies were used as scanning stations. Ruin was scanned with 1 cm, sometime 1.2 and 1,4 cm precision. Only the façade with muqarnas was scanned 0.4 cm precision. Data obtained from laser scanner transferred to Z-Map software. It could not be used well in Autocad software. Therefore drawing was done in Z-Map and then they were transferred to autocad. Besides orthophotos were created in Z-Map software due to DEM model of the ruin and then they were exported to autocad.



Figure 1-2 General View of Aleaddin Kosk Ruin



Figure 2

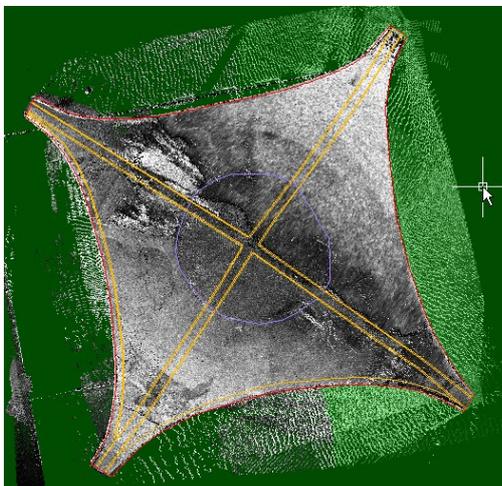


Figure 3: Point Cloud of Concrete Shell in Z-Map

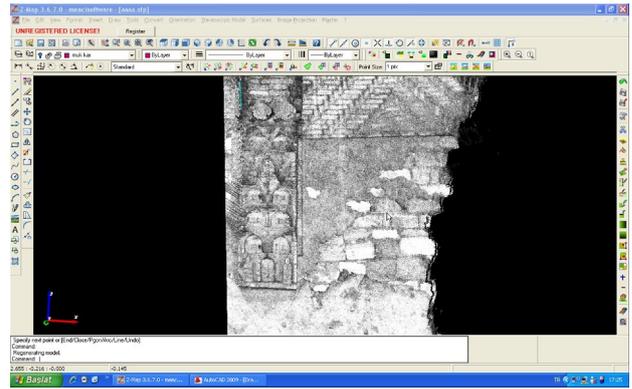


Figure 4: Muqarnas Point Cloud in Z-Map

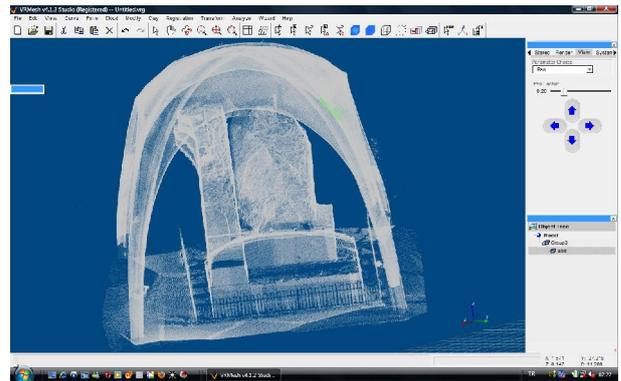


Figure 5: Point Cloud in VR Mesh- Demo version

It was a big advantage to be able to get 2D sections from 3D model because the concrete umbrella surface was too recessed and protruding. Other advantage was to get 2D facades from 3D model. However there were some dark holes in point cloud model which made difficult to generate orthophoto in Z-Map. For this, some orthophotos were created in Photomodeler software. Façade with muqarnas was a large amount of data which could not be opened in autocad. Drawing of the muqarnas is very challenging and difficult with traditional drawing methods. However in Z-Map it was easier to draw section, plan and facades on 2D model. They later exported to autocad.

5.3. Monastery in Sille

Sille is an ancient village in North West part of Konya and 8 miles from Konya. Today it is a neighborhood of Konya Selcuk Municipality. Archeological data shows that this settlement was built 600 years ago. Because of it was located on the road Jerusalem, Rome and Byzantine, it had been a significant religious center. One of the world's oldest and largest monasteries "Ak Manastır" is in the village and gave service approximately 800 years.

This monastery is one of the monasteries of Sille. Today it is in bad condition because of neglect, bad use and weather. It has no roof, only small walls. This monastery was scanned with the same laser scanner as I mentioned above. The ruin was scanned from 4 stations with 1 cm precision. get 3D images to 3D polygonal model, PolyWorks Version 10.0 InnovMetric software was used. Firstly, the binary data provided by Optech ILRIS-3D were parsed using Optech Parser 4.2.7.2. to get point cloud in .IXF format processed by Innovmetric PolyWorks

10.0. Secondly the translated images were imported into PloyWorks InnovMetric software and then merged into one polygonal model.

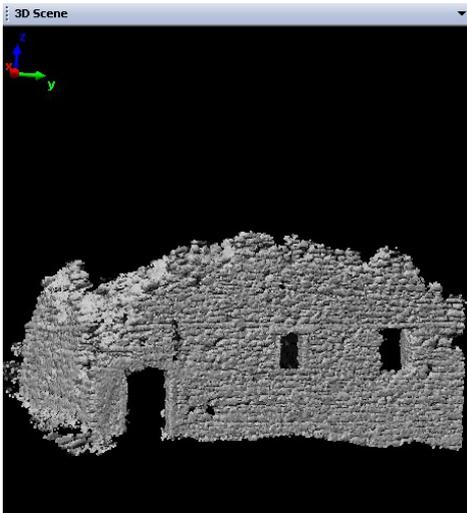


Figure 6: Point Cloud of Monastery in PolyWorks InnovMetric

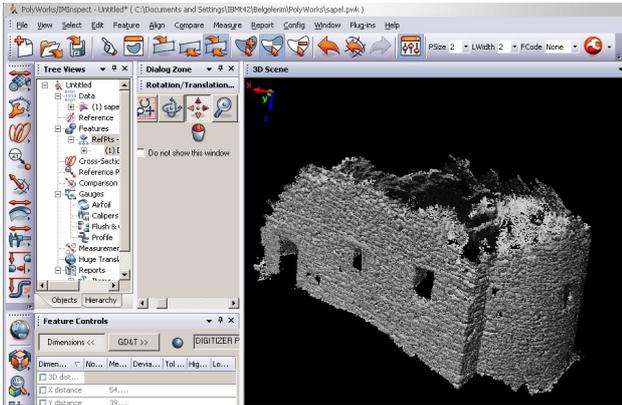


Figure 7: Point Cloud of Monastery in PolyWorks InnovMetric

5.4. Aksaray Sultan Han

Han-caravansary, khan- is a kind of roadside inn where travelers- convoy of soldiers, traders, merchants and their servants- could rest and recover from the day's journey. It is in some Eastern Countries with an open and large courtyard to provide accommodation. Caravansaries most typically were built with a square or rectangular walled with a single portal for leaden beasts such as camels to enter. They have stalls, niches chambers to accommodate for merchants and their servants and animals. Besides, they have fodder for animals, shops for travelers and merchants to dispose their goods.

Sultan Han is 42 km from Aksaray and it is on the Konya-Akasaray road in Sultan Han small town. On it's inscription it is clearly written that this han was built by Alaüddin Keykubat-I.Gyaseddin Keyhüsrev's son- in 1228-1229.

This han was also scanned from different stations. To get 3D images to 3D polygonal model, PolyWorks Version 10.0 InnovMetric software was used. Firstly, the binary data provided by Optech ILRIS-3D were parsed using Optech Parser 4.2.7.2. to get point cloud in .IXF format processed by Innometric PolyWorks 10.0. Secondly the translated images

were imported into PloyWorks InnovMetric software and then merged into one polygonal model

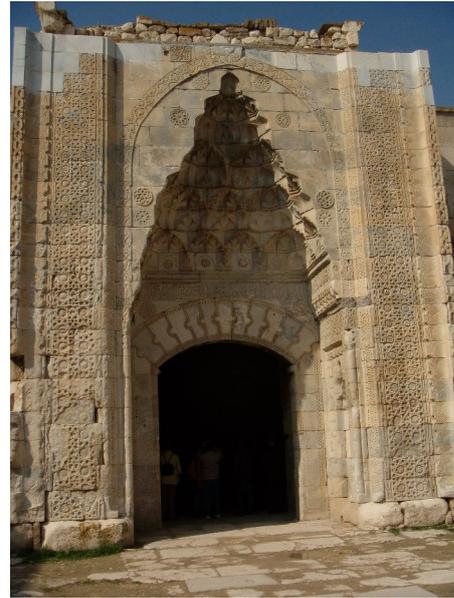


Figure 8: Portal of the Han

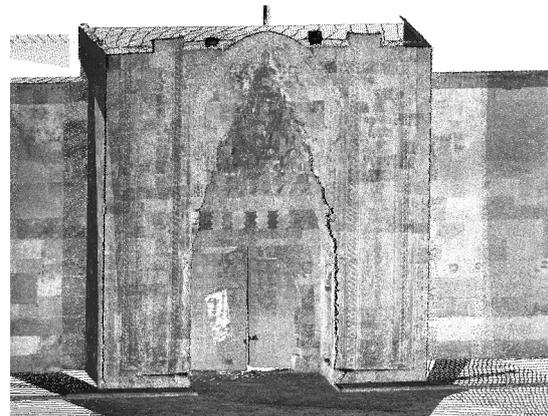


Figure 9: Point Cloud Model of the Portal

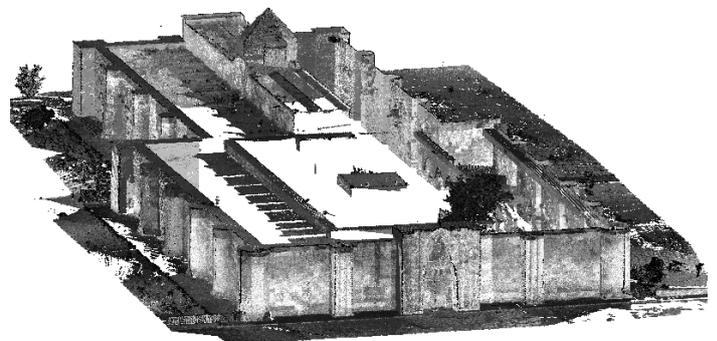


Figure 10: Point Cloud Model of the Han

6. CONCLUSIONS

Laser-based technologies provide 3D support in architectural and urban surveying and documentation with different levels of detail. This support simplifies to get realistic and virtual environments around the buildings and ruins.

To be able to create 3D model provides an additional reading for architectural ruins analysis. All these things help to reach an appropriate strategic approach for documentation of ruins and to evaluate the results with 3D virtual environments. Laser scanner survey could be the fastest solution in order to get geometry of cultural heritage but when appropriate methodology was chosen. The integration of different geometrical data provides unavoidable support for architectural surveys.

It is indisputable that principles guiding preservation and restoration of cultural heritage should be laid on an international basis and each country should follow these basis in its own culture and tradition frame as mentioned Venice Charter before. For the preservation of digital heritage, governments, creators, universities, private and state institutions should effort. Here it can be said that even though the heritage recorded and documented digitally, more international collaborations and information sharing are required. All these information also should be accessible by the possible users and public.

ACKNOWLEDGEMENT

The authors wish to acknowledge for the cooperation and the financial assistance given by the Scientific Research Found (BAP) of Selcuk University for this paper no:10701230.

REFERENCES

Patias, P. “*Cultural Heritage Documentation*”, Commission VI Special Interest Group “Technology Transfer Caravan.

Caroti G., Piemonte A., “*An Integrated Survey for Knowledge and Preservation of a Cultural Heritage: The Albanian Fortified Citadel of Elbassan*”, Commission V, WG V/2

Van Genechten B. , Demeyere T., Herinckx S., Goos J., Schueremans L., Roose D., Santana M., “*Terrestrial Laser Scanning in Architectural Heritage- Deformation Analysis and The Automatic Generation of 2D Cross Sections*”, 22 nd CIPA Symposium, October 11-15, 2009, Kyoto, Japan.

Agnello F., Cannella M., Gentile A., Lo Brutto M., Santangelo A., Villa B., “*Innovative Techniques for Survey and Communication of Cultural Heritage*” , Commission V, WG/V/2

Manea G., Calin A. “*Architectural Photogrammetry and Extension of Conventional Surveying*”

Genovese R.A., “*Architectural, Archeological and Environmental Restoration Planning Methodology: Historic Researches and Techniques of Survey Aiming to Conservation*. CIPA 2005 XX International Symposium, 26 September-01 October 2005, Torino, Italy.

Tucci G, Bonora V., Crocetto N., Nobile A., “*New Technologies for Surveying Building Ruins*”.

Remondino F., Rizzi A., “*Reality-Based 3D Documentation of World Heritage Sites: Methodologies, Problems and Examples*”, 22 nd CIPA Symposium, October 11-15 2009, Kyoto, Japan.

Chevrier C. , Perrin J.P., “*Laser Range Data, Photographs and Architectural Components*”, Commission V, WG V/2