#### **Doctoral School on Engineering Sciences**

Università Politecnica delle Marche

**Extended summary** 

## **Close-Range Survey by Image Processing**

# and Visual Design for Cultural Heritage

Curriculum: Analisi e Progetto dell'Architettura e del Territorio

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**Abstract** The virtual reconstruction of digital models in architecture is the fulcrum of this research. In this research a working methodology for the documentation of good architectural/archaeological value is proposed. Of particular interest, the research has dealt with issues relating to measurement and photo-realistic virtual reconstruction of objects in a digital environment. Low-cost photogrammetry and computer vision have been implemented and tested. Again, using multimedia tools, reliable results were obtained by developing a platform for flexible and efficient working procedures which adheres to the requirements of environmental protection and enhancement of cultural heritage.

Keywords: Spherical Photogrammetry, Image Based Modeling, Visual Design

#### **Problem statement and objectives**

Given an overview of the state-of-the-art cultural heritage technologies, it is clear the distinction between different survey approaches (three-dimensinal active and passive acquisition systems) and computer vision techniques (modeling and rendering) is getting narrow and more complicated in terms of increased integration between cross-curricular elaborations and management systems.

Being aware of this background, a flexible working methodology aimed at cultural heritage documentation can not manage without the synergy effects gained by a smart combination of different survey approaches and visualization methods. A methodological choice of this research is to take under special consideration Image Based Modeling gathering from spherical photogrammetry to automated 3D reconstruction from a sparse photo set.

The scanner 3D, even if on the cutting edge for the cultural heritage documentation, is deliberately not considered because not suitable for a low-cost, "lightweight", flexible and affordable working methodology as the one this research aspires to propose.

Spherical Photogrammetry, developed by Prof. Fangi, is found to be a technique capable of combining join precision, data completeness and low-cost (standard camera and PC). The vast experience gained by Prof. Fangi in digital 3D reconstruction is recognised through his international awards; the performance of his approach where the restitution step goes with homologues point collimation in oriented panoramic images. The tools (made available by Prof. Fangi) for the spherical photogrammetric restitution allows manual monoscopic collimations, making the work time-consuming especially for complex architecture.

Another field of this reaserch is the 3D model visualization, again with a long list of problems to face and dedicated softwares to deal with. Image Based Modeling gives the chance to build surfaces starting from 3D point reconstruction by photogrammetry. Inverse Mapping and Rendering drives the projection of the photo on the surfaces, augmenting the 3D model with its superficial characteristics as color, reflectance and luminance. The 3D model visualization systems (or better known as render systems) allow the exploration and the analysis of reconstructed models according to specific geometric and photometric characteristics. Fulfilling standard and file formats suitable for their sharing become another objective of this research.

Visualization solutions gather from simple interaction monitor to complex stereoscopic real-time rendering engrossing the user into dynamic and engaging 3D experiences to interact with. Still more complex solutions with dedicated software and phisical structure (i.e. Cave Automatic Virtual Environment) allows visitors be surrounded by animated virtual environments and have the feeling to actually be in that place.

The techonologies quoted above have applications in multimedia installations specially connected with architectural/archeological museums nowadays turning from simple storages of artifacts to active places that offer more information, emotive involvement and added values to the visitors experience.

Hereafter (Fig.1) two easy flowcharts try to poin out the main research principles (a) and related methodological steps (b). Double arrows underline the need to adapt each process to the input and/or output requirements.



Fig.1 - Interactive flowcharts describing main research concepts (a) and methodological steps (b)

### **Research planning and activities**

A new work-flow has been developed by means of different methodological choices aimed to improve the metric accuracy and the graphic performance of digital models.

Close range Photogrammetry (Spherical Photogrammetry and Structure from Motion) are used to obtain metric data. Beside, Computer Vision applications (Surface Reconstruction, Inverse Mapping and Real Time Rendering) allow photo-realistic results and high communicative impact.

The main steps this research goes through are:

- Data acquisition: different image set are acquired to produce panoramic images
- Image Pre-processing: stiching procedures allow the production of high resolution panoramic images without distorsion
- Photogrammetric 3D reconstruction: Orientation and Point restitution
- Image Based Modelling: modelling a rough surface, Inverse Mapping with orientation data, real time rendering and model enhancement by means on an interactive process. Photomodeling goes along with the creation of a rough surface over which oriented images can be back-projected in real time. Lastly the model can be enhanced checking the coincidence between the surface and the projected texture.

Another challenge of this reseach is to combine the advantages of two technologies already set up and used in many projects: spherical photogrammetry and Structure from Motion. Experimental results shows how is possible to obtain a 3D photorealistic model using the scale of the spherical photogrammetry restitution to orient automated point clouds.

Moreover the proposed research highlights how is possible to speed up the model reconstruction without losing metric and photometric accuracy. In the same time, using the same panorama dataset, it picks out a useful chance to compare the orientations coming from the two mentioned technologies (spherical photogrammetry and Structure from Motion).

The following figure (Fig.2) sets a sequential flowchart (on the left) beside the interactive and iterative approach developed in this research (on the right).

The interactive Image-Based Modeling (IBM) approach developed goes through different steps (surface reconstruction, inverse mapping and texture projection, real time rendering) and feeds back until an optimized and photo-realistic reconstruction of archaeological /architectural heritage is achieved. Advanced tools are developed to provide high communicative impact.



Fig.2 - Workflow diagrams describing the innovative and iterative approach developed (on the right).

To highlight are not so much the individual design decisions but their integration in an organic solution that starts from data acquisition to the divulgation, publication and museum exhibitions of archaeological / architectural heritage digital reconstruction. The integration is made possible by proprietary tools developed with visual programming language.



Fig.3 -Workflow diagram describing the data processing schema developed

### Analysis and discussion of main results

The developed methodology ensures accuracy, accessibility and a high degree of flexibility for the photo-realistic model reconstruction and, although using low-cost tools and technologies, allows to meet quality standards and professional levels.

The particular attention paid to the interactive visualization has led to develope complete design solutions (architectural structure, hardware and software), particularly suitable for museum installations. Thanks to visual programming language (vvvv), proprietary tools have been developed for photogrammetric survey, interactive multimedia content management, virtual

navigation in immersive environments and calibration of multi projectors on architectural surfaces.

## Conclusions

This application field is found to be specially interesting because needing of cross-curricular collaborations, different working platforms and always high-impact representation solutions. The focus achieved is the definition of a system suitable for the management of survey acquisition data and the provision of innovative services to the visitors and the responsibles for archeological sites: reality-based 3D surveying, modeling and visualization applied to architectures and cultural heritage.

Building the framework of a multimedia project is a complicated job that requires an accurate and careful understanding of the project as a whole (output requirements, mothodological pros and cons). Only in this way the interactive solution will comply with the usabitly standards and will be entirely comprehensible by the users that are now able to orientate themselves through applications and understand their active contents.



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Virtual navigation on touch screen device

Fig.4 - Research experiences of virtual reconstruction and interactive visualization

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