MINISTRY OF NATIONAL EDUCATION
"1 DECEMBRIE 1918" UNIVERSITY OF ALBA IULIA
FACULTY OF HISTORY AND FILOLOGY
DOCTORAL SCHOOL OF HISTORY

ABSTRACT

PhD THESIS

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MODERN TECHNIQUES OF DIGITAL ANALYTICAL PHOTOGRAPHIC DOCUMENTATION APPLIED TO THE FIELD OF CULTURAL HERITAGE

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CONTENTS

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Keywords: cultural heritage, digital heritage, computational photography, digital photogrammetry, 3D model, orthophotomosaic, digital elevation model, panorama, gigapixel, H-RTI (*highlight reflection transformation imaging*), HDRI (*high dynamic range imaging*), DStretch (*de-correlation stretching*), *focus-stacking*, *time-lapse*, cultural landscape, archaeological site, historical monument, artifact, *on-line* publication European digital library.

It is obvious today that the concept of cultural heritage becomes more and more complex, as a consequence the activities involved in conservation and restoration involve now other disciplines of study, while the correlation and interpretations of results and data gains important advantages from the usage of their potential. New computer-related technologies, databases and the internet allow for a much better coordination and integration of various types of data that come from these efforts. As a consequence the recording, documenting and information management methods become essential pieces within the decisional processes that deal with cultural heritage management, now being fully integrated within research activities, investigations, treatment and monitoring. Important evolutions have been recoded lately in relation to the means of prospection and documentation as part of conservation and restoration efforts, with new methods of data collection being created, together with new sensors, visualization installations and interaction platforms, some presented in the following pages.

Within this context the methods and techniques of analytical photographic documentation are seen as an optimal and accessible way of prospection, applicable to all the aspects and contexts encountered in the field of cultural heritage. This assumption is based on their capability of documenting a wide variety of situations with a high degree of complexity, within the requirements of quality and metric accuracy, in a short time and often with a limited budget, delivering in the end very usable and easily disseminated products[1].

[1] E. Dall'Asta, N. Bruno, G. Bigliardi, A. Zerbi, R. Roncella, *Photogrammetric techniques for promotion of archaeological heritage: the Archaeological Museum of Parma (Italy)*, în *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, volume XLI-B5, the XXIII ISPRS Congress, 12–19 July 2016, Prague, Czech Republic, p.243 - 250.

The photographic documentation of cultural heritage has to be accomplished in close cooperation and agreement with the specialists, in order to properly establish the cultural significance of the site, monument and artifact, together with the objectives of the current research. Each project assumes an approach strategy, that will have to choose the appropriate level of documentation, while maximizing the proper use of available resources (human, *hardware* and *software*), within a limited amount of time, in order to reach and properly disseminate the results.

The reality of nowadays is a little bit different from this model. It is recognized, even at an international level that the information technologies being discussed here are the result of advanced sciences such as engineering, topography and so on, benefiting in their respective fields of concise and generally acknowledged standards of operations. The recognition of their involvement in the field of cultural heritage brings also a continuous pressure to adapt to their rapid evolution, in a lot of cases the result being a localized and isolated usage, the technologies being applied without the use of recognized standards and methodologies[2]. In this context we also advocate for the development, introduction, application, testing, acceptance and adoption of clear and universal standards and methodologies, leading to a unitary and concentrated approach on the issues of documenting cultural heritage with the use of digital photography. These standards are essential as they will allow for correct and unified results of the photographical documentation, thus making them viable for long-term use in archiving, trade, interrogation, visualization and presentation as well as information retrieval by various researchers, throughout the world, using the internet and not only.

If the traditional documentation phase for cultural heritage, including analog photographs and drawings, was considered until recently as sufficient in the research efforts of the scientific community, today we can speak of an actual revolution in terms of visual analysis and rendering, brought on by the advances registered in the field of digital technologies. In this respect, documenting using computational photography brings to researchers and also to the wide public a series of three-dimensional interactive and easily distributable on-line products. These digital representations are gradually replacing classical bi-dimensional mediums, like photographs, drawings and films, with the addition of high metric accuracy and also interactivity, for both scientific and educational purposes.

[2] M. Ioannides et al, *Standards in Cultural Heritage: the missing grammar for the digital documentation of the past*, CIPA 2005 XX International Symposium, 26 September – 01 October, 2005, Torino, Italy available on-line at: http://cipa.icomos.org/fileadmin/template/doc/TURIN/861.pdf (May 2015).

The field of computational photography, a largely digital endeavor, and that of computer-based processing are currently working towards creating new solutions of three-dimensional complex and accurate rendering for complex surfaces, structures and textures of cultural heritage, including here historical monuments, archaeological sites and artifacts, with an important impact in the documentation phase, with an added bonus of interest on museum virtual collections, for visitors of all ages[3].

Computational photography can be defined simply as a series of methods and techniques that allow for the creation of new representations, with added information to that provided by the source photographs[4]. For the field of cultural heritage these novel renderings of structure and texture, brought on by digital photographic documentation, are considered to be of paramount importance in the study of monuments, sites and artifacts, facilitating accurate interpretations and not least of all an immediate dissemination of results within the research community and also to the wider public. It is widely accepted the fact that a large portion of our cultural heritage is composed of particularly fragile elements, under constant pressure from varied damaging factors, like accelerated urban development, improper management, aggressive tourism practices, natural disasters and conflicts, and not least environmental pollution.

A recent document, published by the Ministry of Culture and National Identity is the Strategy for culture and national heritage for 2016-2022 (SCPN 2016-2022)[5], a set of public policies for medium term in regards to the administration policy, aiming towards a balanced, durable, smart and widely beneficial development of culture, for all the actors involved in cultural activities and society as a whole. This strategy acknowledges as a priority the elaboration of a unified legislative framework for the protection of natural, built and landscape heritage. Another important document that was released recently also recognizes the legislative necessity and proposes the implementation of a Heritage Code with adequate policies, under the title *The thesis for a Cultural Heritage Code*[6], recommendations that were actually approved during a government session on November 29, 2016.

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[3] S. Soile et al, *Accurate 3D textured models of vessels for the improvement of the educational tools of a museum*, în *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. XL-5/W1, 2013, p. 211 - 217.
[4] C. Schroer, *Advanced Imaging Tools for Museum and Library Conservation and Research*, în *Bulletin of the American Society for Information Science and Technology*, 38(3), 2012, pp. 38-39.
[5] The digital version of this document, in course of approval is available at: http://www.cultura.ro/sites/default/files/inline-files/_SCPN%202016-2022inavizare.pdf (Mai 2017).
[6] The digital version of this document is available at: http://www.cultura.ro/sites/default/files/inline-files/TEZE_PREALABILE_CODUL_PATRIMONIULUI_fin041016.pdf (Mai 2017).

One of the main conclusions brought on by these policy documents is that in the case of Romania, at a legislative level we have a mimetic evolution, associated mainly with the adhesion process to the European Union and in a lot of cases they are also reactions brought on by public pressure as a result of insufficient administrative practices. Another factor of change is the pressure brought on by the accelerated development of infrastructure, with large national projects that have impacted and in some cases destroyed heritage during their implementation, even at a landscape level. Another pressure is brought on by the pressure of urban development, especially towards built heritage, with numerous monuments being affected and even completely demolished. The degradation of rural landscapes and even that of the traditions themselves can also be considered a conclusive example.

Within this context it is obvious that, at least for our country, there is a stringent necessity and also an opportunity to integrate an accessible system of analytical photography-based documentation, using modern methods and techniques, some described also within these pages. In a lot of instances the term *digitization* and *digital* is used in relation with the activities of transforming analog products in digital versions, an example being the scanning of document archives. In only a few instances it is acknowledged the value and importance of directly producing digital heritage, an example being the creation of 3D models from digital photos, through photogrammetric techniques. Also, the term *digitization* is often limited to describe only a simple digital photography of an artifact, monument or site, a situation often encountered in the description of projects[7].

One of the main arguments for our attempts of establishing an integrated system of digital documentation is the recent relative accessibility of a series of powerful means of analytical photographic methods of documentation, like photogrammetry, gigapixel panoramas and so on. Even though not all these methods are easily available to heritage operators in Romania, partly due to the advanced technological language used and partly due to financial possibilities, they are largely speaking within reach. As a consequence we have promoted within these pages the usage of minimal and internationally recognized rules when photographing items of cultural heritage, like those known as CIPA 3X3[8],

[7] I. Oberländer-Târnoveanu, *Identitatea culturală şi patrimoniul digital: proiecte, reţele şi portaluri*, în *Cibinium 2001 – 2005. Identitate culturală şi globalizare în secolul XX – cercetare şi reprezentare muzeală*, Editura ASTRA Museum, Sibiu, 2006, p. 41-48.

[8] P. Grussenmeyer, K. Hanke, A. Streilein, *Architectural photogrammetry* in M. Kasser, Y. Egels, (ed.) *Digital Photogrammetry* 2002, p. 300-339. O versiune sintetică a acestor reguli este disponibilă (in engleză) la: http://cipa.icomos.org/fileadmin/template/pdf/3x3-23_10_2013.pdf (Mai 2015).

leaving an open opportunity for later processing to be made by photogrammetry specialists.

Paraphrasing the Chinese philosopher Lao Tze we can argue that all these issues and problems related to Romanian cultural heritage can be seen as many opportunities to positively change things. The cultural heritage is in Romania the subject of current strategy debates and discussions, like the aforementioned *Strategy for culture and national cultural heritage between 2016 - 2022*, one conclusion being that Romania is not lacking in legislative means towards the needs of cultural heritage, as most of the essential laws are quite modern and recent, all issued within the last 20 years. Nevertheless there are multiple initiatives that have since amended these laws, rendering them insufficient in terms of protecting the cultural heritage, a situation hailed by part of the civil society also being the fact that the norms of practice that accompany them are insufficient. All of these issues were brought on to sustain a public agenda for the creation of a unified Code for Heritage, as early as the year 2008.

We can argue here that this insufficient definition of the legislative framework can be seen as an opportunity to integrate these new and modern solutions of scientific evaluation and research as a mandatory step for every museum and also for every newly deposed restoration and conservation project. It is well known to specialists the moment in which a digital topographical survey, using the national Stereo70 system, became mandatory for any archaeological research activity[9]; a similar moment is needed to introduce the photogrammetric method as a mandatory documentation practice for monuments, before and after restoration and also as part of continuous periodical monitoring efforts.

Another opportunity is brought on by the sedimentation of methodologies regarding the international platforms used to disseminate digital content, an example being the European digital library, *Europeana.eu*[10]. Lately, using the financial support offered by various national and international programs, an accent was placed on transforming all physical cultural heritage into a digital correspondent, from artifacts and works of art and also monuments, landscapes and even intangible heritage. Within this framework 3D models have found their place with a certain difficulty, only in the last few years we benefited from an accepted methodology of visualization. In Romania, the concept of a

[9] ***, The procedure for issuing of archaeological research authorisations, published in Monitorul Oficial on 04.10.2010.
[10] D. Matei, , *Spre* Europeana.eu*: o introducere în bibliotecile digitale*, CiMEC, 2009, 186p.

virtual museum is widely acknowledged, but in most cases only as a collection of bi-dimensional digital representations (digital photographs) of objects or monuments. Three-dimensional reconstructions can be seen in this case as the next evolutionary step in creating virtual collections and this subject is addressed by our proposal of methodology regarding photogrammetric processing.

Therefore this paper was generally structured as an argument for the transformation and adaptation of the photographic documentation phase within the analysis of cultural heritage in response to the new computational technologies available and not last to the modern research directions observed in the international environment. Our case studies can be seen in this context as a strong argument, as they involve a wide variety of cultural heritage items.

In the introductory chapter we bring forward the main objective of our research, together with the strategic framework in which these methods and techniques can be implemented, in agreement with the necessities and opportunities recently identified within the Romanian and international scientific communities.

The second chapter, titled **Photographic documentation of cultural heritage** is structured as an account of the history of photography as well as an argument for the importance of photographic documentation of cultural heritage, with a presentation of national and international context on this issue, followed by a n introduction in the concept of computational photography.

The third chapter, titled **The method of digital photogrammetry and its applications in documenting cultural heritage** is exclusively dedicated to digital photogrammetry, considered by us to be the most adequate and also the most accessible computational method for the specialists of this field. The method is presented strictly from the point of view of cultural heritage documentation, with bibliographical references made to case studies from the same field of study. An introduction brings forward the well established international institutional framework, followed by a definition and a short history, with references to the basic principles and main types of photogrammetric documentation, benefiting from numerous illustrations of correct (ideal) and incorrect uses.

The fourth chapter, titled **Complementary methods and techniques of photographic documentation for cultural heritage** reunites a series of complementary methods of computational photography, with a more detailed approach on the gigapixel panorama and H-RTI methods. Given the fact that they represent sort of secondary approaches, the techniques of HDRI, DStretch, focus-stacking and timelapse are being

treated in a succinct manner, with a presentation of the theoretical principles, equipment and software used and some relevant case studies.

The fifth chapter, titled **Computational photographic documentation of immovable cultural heritage - case studies** comprises, next to a short legislative definition of the term immovable heritage, a series of representative case studies, from complex documentation of cultural landscapes to the documentation of archaeological sites and historical monuments. The accent falls on the type of heritage, the methods described in the previous chapters being used in a complementary manner, as complex studies. Each case is presented shortly within the context of similar researches, together with relevant references. The specific use of each method is presented next to the main results that could be extracted, making use of a comprehensive set of plates. Once some aspects of the methodology are described they are not revisited in the following case studies, only mentioned. In some cases the results allowed us to issue a hypothesis or a conclusion, in this case they were briefly discussed at the end.

Of a similar approach we have the sixth chapter, titled **Computational photographic documentation of movable cultural heritage - case studies**, this time having as subject elements of movable heritage, ordered in respect to material type. In approaching the relevant case studies we intended to apply our methods to a high number of material types, the list comprising stone tools, bone and ivory, pottery, figurines, vegetal and plant imprints on pottery and burnt clay, stone inscriptions, coins and medals, cameo gemstones, stone statues, icons painted on wood, canvas paintings, a paper diploma and even an archaeological textile.

Chapter 7, titled **Digital cultural heritage - capitalization and on-line publication of results**, is dedicated to the concept of digital cultural heritage, a modern concept that reunites all of our products, together with an overview of the main principles of archival and on-line publication, with details on the chosen solutions for the case of computational photography.

The final chapter reveals some of the conclusions reached on the basis of these case studies, with some explanations on the way that computational photography answers the particular demands of cultural heritage documentation in our country. The 118 plates provided are revealing only the case studies we considered to be more adequate for each method. For a complete list of on-line published digital products see ANNEX 2, with a total of 97 3D models and a further 95 gigapixel panoramas, accessed via hyperlinks.

Among the ANNEXES we have a useful methodological synthesis together with lists that were not included in the main body of text due to space restriction.

A report from 2016, issued by the European Union on the subject of cultural heritage digitization, for a period between 2011 - 2015[11], revealed a "good progress" with the majority of member states, in the case of Romania being mentioned an ambitious national strategy that was intended to counteract the system deficiencies that were noticed to this date, the most eloquent example being the completion of only 21% of the proposed digitization goal in the aforementioned period. If this digitization aims in particular the artifacts and cultural heritage found within libraries, museums or private collections other issues can be identified for Romania in the case of immovable cultural heritage, cultural landscapes, archaeological sites and historical monuments, many of them in an endangered state. This is the context in which we can state that the use of direct and accessible computational photography methods of documentation is no longer a luxury but a necessity.

The London Charter mentions, as early as 2006, the necessity of using methods and techniques of 3D visualization for the field of human sciences, with rigorous intellectual and technical means, following established standards, in order to achieve a maximum potential for research, communication and conservation of cultural heritage. With this aim in mind we can state that a first and most important goal of this thesis is the presentation towards specialists in Romania of some of the best and most accessible solutions in the field of photographic documentation of cultural heritage, applied from cultural landscapes to archaeological sites, historical monuments and artifacts.

The digital photographic documentation is presented in these pages as providing probably the most important and accessible means of recording structural characteristics of cultural heritage, from macro to micro level. They can be accessed by using simple guidelines at the time of photography thus opening a path towards computational usage. Once these principles are applied it is possible to extract modern analytical products that are crucial in conservation - restoration works and not least resulting in attractive means of digital dissemination, towards specialists and also the wider public.

Based on these conclusions and also on the experience gathered in these years we can make some general proposals for the directions to be followed within the practice of

[11] ***, Cultural heritage Digitisation, online accessibility and digital preservation. Report on the Implementation of Commission Recommendation 2011/711/EU, accesibil online la http://ec.europa.eu/information_society/newsroom/image/document/2016-43/2013-2015_progress_report_18528.pdf (Mai 2017).

photographical documentation in Romania. One of the most obvious suggestions is the insertion of these modern methods and techniques within the general flow of cultural heritage documentation, given their immense potential. Their efficiency and flexibility is fully proven by our case studies, the financial cost of their involvement being within the reach of every institution that runs research projects. A second proposal is aimed at the specialists that currently run such documentations as part of their research and implies that they should always use the minimal standards of photography mentioned by the CIPA 3X3 rules, thus ensuring the possibility of a later photogrammetrical processing, if needed, for example by another more specialized team. Another proposal concerns the revitalization of the idea of photographic laboratories within larger museums, especially those that carry out regular research. This is a response to the current trend that saw the disappearance of this specialty from most museums, mainly because of the specificity and accessibility of digital photography. The integration of such special methods of computational photography would function much more coherently and organically within such an environment, allowing those museums to open themselves to the virtual domain, via virtual collections, a necessity that is more and more acute at the moment. Such an approach will allow these museums to become more easily a constant supplier of digital cultural heritage, towards centralizing institutions and digital platforms, like *Europeana.eu*, thus solving the setback mentioned for Romania. A great potential can also be identified in the provision of extremely useful educational materials for schools, thus promoting cultural heritage values. Some of these aspects were tested during the practical courses held with students from the history specialty of our "1 Decembrie 1918" University of Alba Iulia.

Another important aspect that became obvious during this research is the fact that none of these methods could actually document the entire complexity of a cultural artifact / structure solely on their own. It is obvious to us that a hybrid approach is much more adequate and sometimes essential, the choice of methods being made based on the advantages and also on the limitations of each, also considering the time and financial budgets available. As a conclusion the process of documenting cultural heritage implies a careful and detailed planning, taking into account all the involved factors, towards guaranteeing a truly useful outcome, in the spirit of the set research topics. It is essential that the heritage specialist be familiarized with the principles and also the extraordinary potential brought on by these methods, in order to make informed decisions while establishing research objectives. This was also one of the main goals of our thesis.

Given all these conclusions we can state with certainty that our methods are providing researchers with considerable analytical possibilities while also providing popularization means, for all the auxiliary sciences of history. Their non-invasive character, the implicit photo-realism, the metric accuracy and high level of detail offered, together with their flexibility and portability are recommending their full implementation among the standard operations of documentation regarding the cultural heritage of Romania and not only. The bibliography on this subject is also an indication that these methods are already intensely used by museums and research facilities throughout the world, in some cases they are already part of the standard flow of analysis, an objective that should be followed also by our heritage management institutions.

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