Marinos Ioannides (Ed.)

LNCS 10605

Digital Cultural Heritage

**Final Conference
of the Marie Skłodowska-Curie Initial Training Network
for Digital Cultural Heritage, ITN-DCH 2017
Olimje, Slovenia, May 23–25, 2017, Revised Selected Papers**

Initial Training Network for Digital Cultural Heritage
ITN DCH

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Cover illustration: The images on the cover are taken from the paper "Rapid Reconstruction and Simulation of Real Characters in Mixed Reality Environments" by M. Papaefthimiou et al. on page 275. They represent the reconstructed monument of ASINOU, which belongs to the UNESCO WHL (http://whc.unesco.org/en/list/351). The upper image illustrates the monument and the lower one the virtual reality representation of the Priest and the frescos of the monument. The church is located on the southern part of Nikitari village on the foothills of the Troodos Mountains in Cyprus (https://www.byzantinecyprus.com/).
The ASINOU monument has been used as the first case study during the research training activities of all the ITN-DCH fellows (http://www.itn-dch.eu/index.php/case-studies/asinou/).

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Preface

The Marie Skłodowska-Curie Initial Training Network for Digital Cultural Heritage: Projecting Our Past to the Future (acronym, ITN-DCH) was the first and one of the largest fellowship projects in the area of the e-documentation/e-preservation and CH protection funded by the European Union under the EU FP7 PEOPLE research framework (www.itn-dch.eu). The project started on October 1, 2013, and its consortium comprises 14 full partners and 10 associate members covering the entire spectrum of European CH actors, ranging from academia, research institutions, industry, museums, archives, and libraries. The project aimed to train 20 fellows (16 ESRs and 4 ERs – 500 person months) in the area of CH digital documentation, preservation, and protection in order to provide them with a strong academic profile and market-oriented skills, which will significantly contribute to their career prospects. The consortium and the fellows training program were supported by a prestigious advisory board.

ITN-DCH aimed—for the first time worldwide—to analyze, design, research, develop, and validate an innovative multidisciplinary and intersectorial research training framework that covers the entire lifecycle of digital CH (DCH) research for a cost-effective preservation, documentation, protection, and presentation of cultural heritage. CH is an integral element of Europe and vital for the creation of a common European identity and one of the greatest assets for steering Europe's social and economic development as well as job creation. However, the current research training activities in CH are fragmented and mostly designed to be of a single discipline, failing to cover the whole lifecycle of DCH research, which is by nature multidisciplinary and intersectorial. The training targeted all aspects of CH ranging from tangible (books, newspapers, images, drawings, manuscripts, uniforms, maps, artifacts, archaeological sites, monuments) to intangible content (e.g., music, performing arts, folklore, theatrical performances) and their inter-relationships. The project aimed to boost the added value of CH assets by re-using them in real application environments (protection of CH, education, tourism industry, advertising, fashion, films, music, publishing, video games, and TV) through research on (a) new personalized, interactive, mixed, and augmented reality-enabled e-services, (b) new recommendations in data acquisition, (c) new forms of representations (3D/4D) of both tangible/intangible assets, and (d) interoperable metadata forms that allow for easy data exchange and archiving.

The project was structured in training modules and had as a milestone event a public final conference open to the public. The ITN-DCH fellows as well as other researchers from outside our project had to present their latest research results. The ITN-DCH fellows were responsible for the planning and organization of this unique event, which took place at Olimje in Slovenia in May 2017.

The presented papers were reviewed by the majority of the fellows and their supervisors and illustrate the state of the art in research and development in the area of DCH.

Here, we present 29 papers, selected from more than 100 submissions, which focus on interdisciplinary and multidisciplinary research concerning cutting-edge CH informatics, physics, chemistry, and engineering and the use of technology for the representation, documentation, archiving, protection, preservation, and communication of CH knowledge.

Our keynote speakers Eleanor E. Fink, Alex Yen, and Pavlos Chatzigrigoriou are not only experts in their fields but also visionaries for the future of CH protection and preservation. They promote the e-documentation and protection of the past in such a way for its preservation for the generations to come.

We extend our thanks to all authors, speakers, and everyone whose labor and encouragement made the ITN-DCH final event possible. The Organizing Committee, whose members represent a cross-section of archaeology, physics, chemistry, civil engineering, computer science, graphics and design, library, archive, and information science, architecture, surveying, history and museology, worked tenaciously and finished their work on time.

We express our thanks and appreciation to all the project advisors for their enthusiasm, commitment, free-of-charge work and support for the success of this project and the event. Most of all we would like to thank all the ITN-DCH fellows and the European Commission, CIPA, ISPRS and ICOMOS that entrusted us with the task of organizing and undertaking this unique event.

December 2017 Marinos Ioannides

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Acknowledgment and Disclaimer

The Marie Skłodowska-Curie Initial Training Network for Digital Cultural Heritage (ITN-DCH) final conference has been part of the training activity of all the project's fellows, supported by the EU FP7-PEOPLE 2012/3 Programme.

However, the content of this publication reflects only the authors' views and the European Commission, the CIPA, ICOMOS, Cyprus University of Technology, all the ITN-DCH partners/institutions, supervisors and associated partners/institutions, the Slovenian Association for Earthquake Engineering (SAEE) and the EU projects FP7 PEOPLE ITN2013 ITN-DCH and IAPP2012 4D-CH-WORLD, the DARIAH-EU ERIC, the EU DARIAH-CY, the EU H2020 INCEPTION, the EU H2020 CSA ViMM, the CIP ICT-PSP Europeana-Space, the CIP ICT-PSP LoCloud and the EU COST Action TD1406 projects are not liable for any use that may be made of the information contained herein.

Contents

3D Data Acquisition and Modelling of Complex Heritage Buildings

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Abstract. The ongoing EU funded project "INCEPTION – Inclusive Cultural Heritage in Europe through 3D semantic modelling" proposes a workflow aimed at the achievements of efficient 3D digitization methods, post-processing tools for an enriched semantic modelling, web-based solutions and applications to ensure a wide access to experts and non-experts. Nevertheless, the generation of high quality 3D models can still be very time-consuming and expensive, and the outcome of digital reconstructions is frequently provided in formats that are not interoperable, and therefore cannot be easily accessed. This challenge is even more crucial for complex architectures and large heritage sites, which involve a large amount of data to be acquired, managed and enriched by metadata. In order to face these challenges and to start solving the issues of the large amount of captured data and time-consuming processes in the production of 3D digital models, an Optimized Data Acquisition Protocol (DAP) has been set up. The purpose is to guide the processes of digitization of Cultural Heritage, respecting needs, requirements and specificities of cultural assets, by dealing with issues such as time-consuming processes and limited budget available for 3D documentation, accuracy of 3D models, integration of metadata and semantics into the 3D model and links with multimedia information. The DAP can be followed during the planning and performing of a 3D laser scanner survey of Cultural Heritage, and it is referred to architectural, archaeological, urban and site scales.

Keywords: 3D data acquisition · Semantic modelling · Digital heritage
Optimized data capturing · Heritage documentation

1 Introduction

The integration of digital data and the possibilities of reusing digital resources is an important challenge for protection and conservation of the historic buildings as well as for efficient management in the long term [1]. The need of a future reusable broad and descriptive source of measurement data demands new applications to facilitate information accessing, collected in three-dimensional databases without compromising the quality and amount of information captured in the survey.

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The identification of the multi-function and multi-scale role of the model allows the exploitation of uneasy and complex resources (obtained by the collection of geometric shape and not just of the architectural and urban context) at different levels, over time and by different actors. Here it is the value of accessibility/affordability of the process that until now has been barely allowed spatial scale but through a mere visual navigation often uninterpreted, an approach very far from the knowledge, understanding and conservative needs. The combination of innovative methodologies and protocols, processes, and devices, enhances the understanding of European Cultural Heritage by means of 3D models bringing new knowledge, collaboration across disciplines, time and cost savings in the development and use of 3D digital models [2] (Fig. 1).

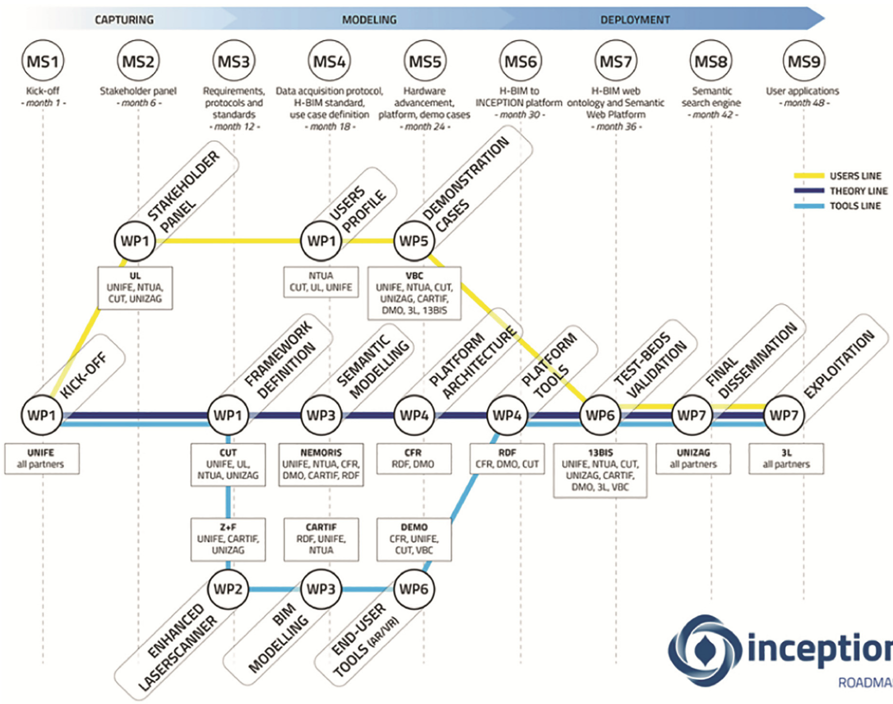

Fig. 1. The INCEPTION roadmap, showing the main project steps under “Capturing”, “Modeling” and “Deployment” phases.

In this framework, the project INCEPTION “Inclusive Cultural Heritage in Europe through 3D semantic modelling” [3] is dealing with several challenges related to the 3D documentation and modelling of heritage assets. Starting from the setting up of a common framework for knowledge management, advancement into the integrated 3D data capturing methodology has been accomplished, in order to face the semantic modelling for Cultural Heritage buildings in a H-BIM environment. The main outcome will be the INCEPTION platform, an open-standard web semantic platform for accessing, processing and sharing interoperable digital models. On-site and off-site applications will be developed for a wide range of users.

The project, lasting four years, started in June 2015 and it is now approaching the third year of development. The first stage related to the enhancement in 3D acquisition processes, has been accomplished by improving first of all the integrated data capturing and digital documentation methodologies.

2 3D Survey of Complex Heritage "Spaces": The Geometric Dimension

Within INCEPTION, the architectural space becomes the foundations, the common core and the "connection" for the creation of a protocol for optimizing the 3D documentation of Cultural Heritage. The methodology set as a priority the unconventional features/ geometries, unique and complex within heritage, avoiding the "segmentation" of data acquired and facilitating data access and use through an inclusive approach.

Nowadays, the methodologies mainly used, face the problem of the complexity of current tools and the processing of results obtained by using new technologies in representation over the 2D and 3D conventions. These outcomes are very often surprising but sometimes impoverished in the expressive vocabulary of the representation of a proper reference model, which allows investigating the tangible material as well as the intangible intentions.

Architectural space geometry is an essential tool to handle the spatial expression of a drawing useful to accomplish knowledge and conservative process; survey and representation of heritage architectural spaces, gives the opportunity to explore the form from the two-dimensionality to the three-dimensionality of reality and vice versa.

INCEPTION innovation [4] is related to the focus on the heritage spaces (at architectural and urban scale), one of the most important "containers" of cultural expressions identified in the evolution of the concept of European identity. The project develops an integrated approach, it is able to investigate the potential of spaces in order to create new cultural connections and awareness; the architecture is an outstanding example of the multi-layered conceptual dimension of European heritage.

The 3D survey of heritage architectural space needs a common protocol for data capturing and related enhancement of functionalities, capabilities and cost-effectiveness of technologies and documentation instruments. The protocol considers the uniqueness of each site, quality indicators, time-consumption, cost-effectiveness, data accuracy and reliability, additional data and semantic proprieties to be recorded for heritage applications and adaptability to different sites with different historical phases.

The integration of digital data and the possibilities of reusable digital resources is an important challenge for protection and conservation of historical buildings as well as for efficient management in the long term. The need for a future reusable broad and descriptive source of measurement data demands new applications to facilitate information accessing collected in three-dimensional databases without compromising the quality and amount of information captured in the survey (Fig. 2).

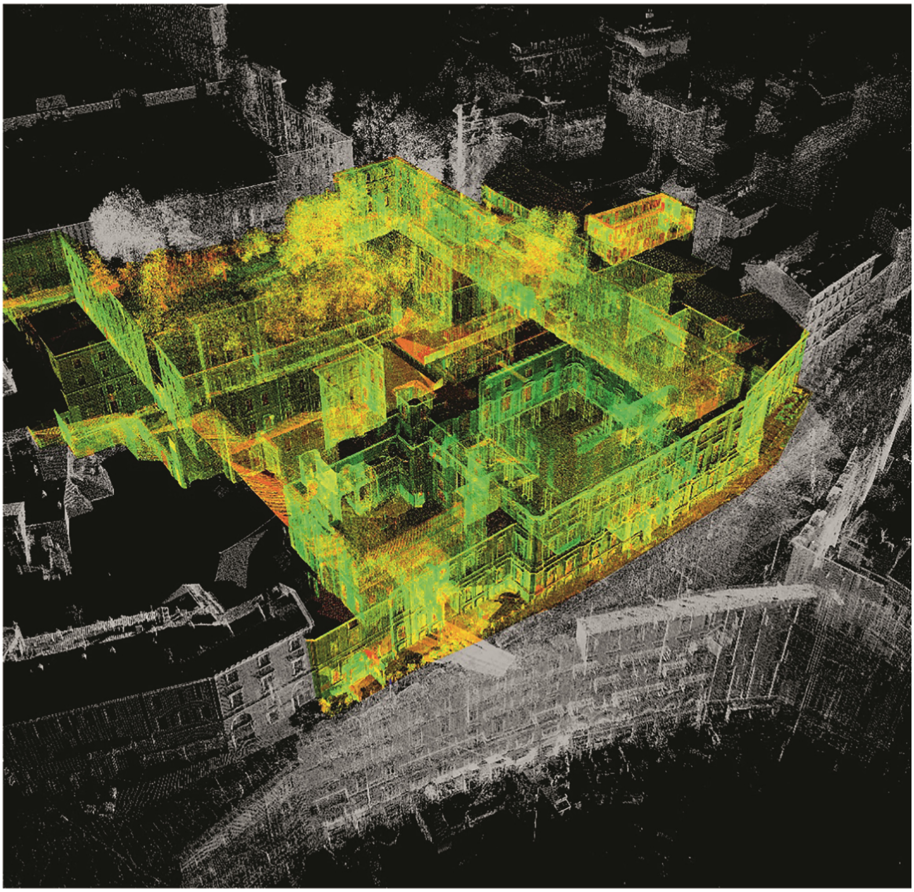

Fig. 2. Example of 3D survey of a complex heritage site, Palazzo Arese Litta in Milan, Italy; visualization of the 3D point cloud of the overall building and the surrounding (DIAPReM).

The 3D survey of heritage "spaces" means:

- to understand how the space (defined by its geometric morphometric characteristics) can be the interface/connection with time dimension; the space/time relation can be an easy, (and affordable) understandable (and therefore inclusive) metaphor of memory (collective and European);
- to understand how space (architectural, urban and environmental) has its own dynamic characteristics that not only gives the chance of an understandable navigation and discovery but also identifies the option of choosing which is the basis of the definition of culture: what to choose and to store in a certain time and why;
- to understand that only through space (and its complexity) it is possible to collect a high level of multi-functional knowledge strongly linked to the multi-scale representational process.

Working at heritage architecture and site scale will allow the identification of the Cultural Heritage buildings semantic ontology and data structure for information catalogue. Current project activities are addressed to a modelling approach within the 3D semantic Heritage-BIM: the integration of semantic attributes with hierarchically and mutually aggregated 3D geometric models is indispensable for management of heritage information. 3D parametric and semantic modelling will lead to the development of semantic 3D re-constructions of heritage building and sites, integrated with additional documents (i.e. pictures, maps, literature) and intangible information (Fig. 3).

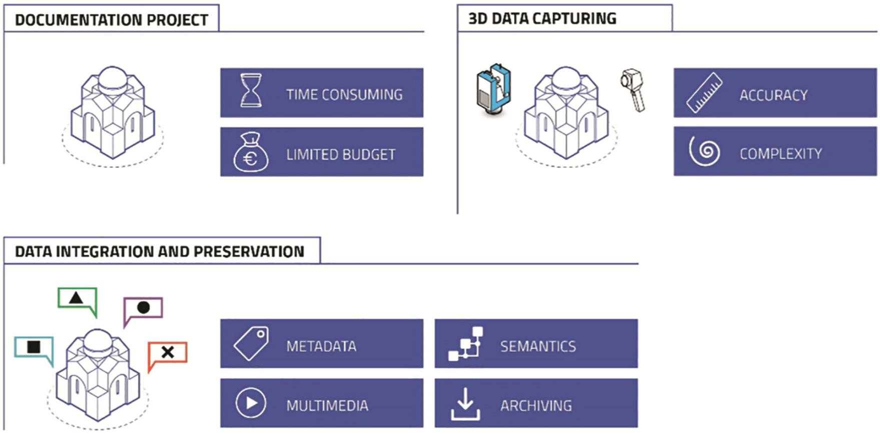

Fig. 3. Main challenges in 3D documentation and conservation for Cultural Heritage related to the main workflow steps.

2.1 Main Challenges in Digital Documentation

The work on 3D data acquisition and modelling of complex heritage buildings has been developed starting from a broader methodological framework. Beyond technical definitions and in-depth specifications regarding measuring instruments and data capturing devices, it is essential to frame the 3D data capturing within the specific field of Cultural Heritage and within the overall concept of heritage documentation [5].

Heritage documentation is basic for understanding our legacy and our cultural identity. Documentation processes are becoming more and more relevant and effective in order to collect data and information allowing knowledge, understanding, assessment, preservation and management intervention on Cultural Heritage.

New technologies and instruments now available, allow us to create integrated digital databases able to collect dimensional data, information related to structures and materials, state of conservation, diagnostic analysis and historical data, making the data capturing an overall integrated process in supporting sustainable decision strategies for conservation, restoration and enhancement of Cultural Heritage.

In this framework, digital technologies are very relevant because they are able to survey very rapidly heritage buildings and sites by collecting millions of spatial coordinates. This 3D acquired data can be used not only for documentation and monitoring purposes but also for digital application (such as virtual tours, virtual tourism, digital reconstructions, etc.) and to create integrated 3D databases for preservation, diagnostics, restoration, and management procedures.

Methods and processes for data collection are continuously developing and today are characterized by effective interdisciplinary. Skills on 3D laser scanner survey, diagnostic procedures and historical researches, as well as about environmental condition assessment or management of metric and dimensional data support the INCEPTION vision of integrated digital documentation for Cultural Heritage assessment.

3 The INCEPTION Optimized Data Acquisition Protocol

In order to face the main challenges related to 3D surveys of complex architectures and to start solving the issue of the large amount of captured data and time-consuming processes in the production of 3D digital models, an Optimized Data Acquisition Protocol (DAP) has been set up [6]. The purpose is to guide the processes of digitization of Cultural Heritage, respecting needs, requirements and specificities of cultural assets, by dealing with the following issues:

- time consuming processes and limited budget available for 3D documentation,
- accuracy of 3D models,
- complexity of the heritage documentation,
- integration of metadata and semantics into the 3D model [7],
- link the 3D object with other multimedia information such as images, structural analysis data, materials, preservation records, etc.,
- archiving of 3D digital records using widely accepted standards.

The assessment and optimization of 3D data acquisition tools allow the improvement of methodological and technological advancement for 3D data acquisition and development of procedural standards [8]. The output is a methodological report for documenting Cultural Heritage by means of 3D data capturing, within a more general methodological procedure of heritage documentation. Since every cultural asset is unique and requires investigations "case by case", according to many different characteristics and to the main purposes of survey and documentation procedures, the protocol is set as flexible guidelines considering different kinds of instruments and devices, different accuracies and levels of detail, etc., in addition to site specifications and the uniqueness of Cultural Heritage.

The DAP can be followed during the planning and performing of a 3D laser scanner survey of Cultural Heritage, and it is referred to as an architectural, archaeological, urban and site scale. It is also referred to as data management (scan registration, data verification) data storage and archive. It is both a methodological procedure and an optimized workflow specification.

The main aims of the INCEPTION DAP are:

- to set up an optimized procedure, based on principles of simplicity and efficiency, for surveying heritage buildings and sites by using different 3D data capturing instruments;

- to provide a workflow for a consistent development of survey procedures for tangible Cultural Heritage and a set of instructions and guidelines for collecting, presenting and storing data;
- to provide a tool able to guide a 3D data capturing procedure able to generate 3D models accessible for a wide range of users;
- to enhance the accuracy and efficiency of 3D data capturing by documentation and instruments integration;
- to support a cost effective and time saving procedure;
- to serve as the basis for the enhancement of functionalities of data capturing technologies and documentation instruments;
- to close the gaps between technical fieldwork and modelling in 3D data capturing.

3.1 Data Acquisition Protocol

The DAP provides a workflow for a consistent development of survey procedures for tangible Cultural Heritage and defines a common background for the use of H-BIM across multiple building types and for a wide range of technical users. Furthermore, this protocol will be useful for any agency, organization or other institution that may be interested in utilizing survey procedures aimed at 3D H-BIM semantic models creation and their implementation for the INCEPTION platform. This protocol is under application and tested on project demonstrations cases, and it will be further improved according to the specific test-bed procedures scheduled in the INCEPTION research project [9].

The DAP is intended to ensure uniformity in 3D digital surveying for all the buildings that will be part of the INCEPTION platform [10]. This protocol considers a wide range of 3D data capturing instruments because of multiple users and different techniques related to specific disciplines. Furthermore, 3D survey instruments and techniques continue to evolve, and this protocol will continue to be reviewed and updated to reflect advances in industry technology, methodology and trends; in every case, the protocol application will ensure data homogenization between surveys tailored to different requirements.

The survey workflow is split into eight main steps that define specific requirements and their related activity indicators:

1. Scan plan
2. Health and safety
3. Resolution requirements
4. Registration mode
5. Control network
6. Quality control
7. Data control and verification
8. Data storage and archive (Fig. 4).

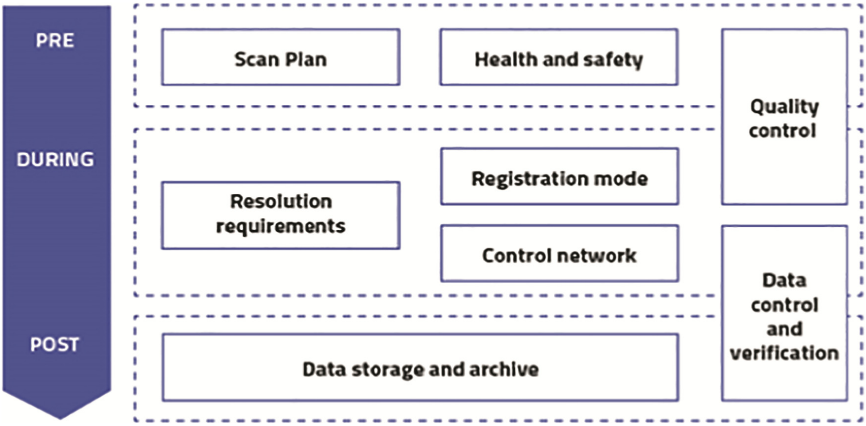

Fig. 4. Workflow steps and activity indicators.

Each step of the workflow is intended as a set of "questions" that become a measuring system to verify the requirements of the survey, and the ability of finding the right answer to define the level quality. On this assumption, every single question becomes an activity indicator [11] that contributes to get a specific evaluation ranking. Not every activity indicator is always compulsory: if in the survey campaign only the minimum number of questions find an answer, the capturing procedure will be classified in the lower ranking. Conversely, if each element is taken into account, the ranking will be the highest.

In the case of direct measurable procedures, the specific activity indicator defines a range of accepted values. Instead, when alternative procedures are available, the protocol specifies their compliance with evaluation categories. For this purpose, there are four incremental categories defined as following:

B: This is the minimum evaluation category to be compliant with the INCEPTION platform. It is intended to be used for very simple buildings or for the creation of low-detailed BIM model for digital reconstruction aimed at VR, AR and visualization purposes. In this case, the metric value of the model is less important than the morphological value.

A: This evaluation category is suitable for documentation purposes where the metric and morphological values are equivalent in terms of impact on the survey that needs to be preliminary scheduled and designed. The registration process of 3D captured data cannot be based only on morphological method but it should be improved by a topographic control network or GPS data (Fig. 5).

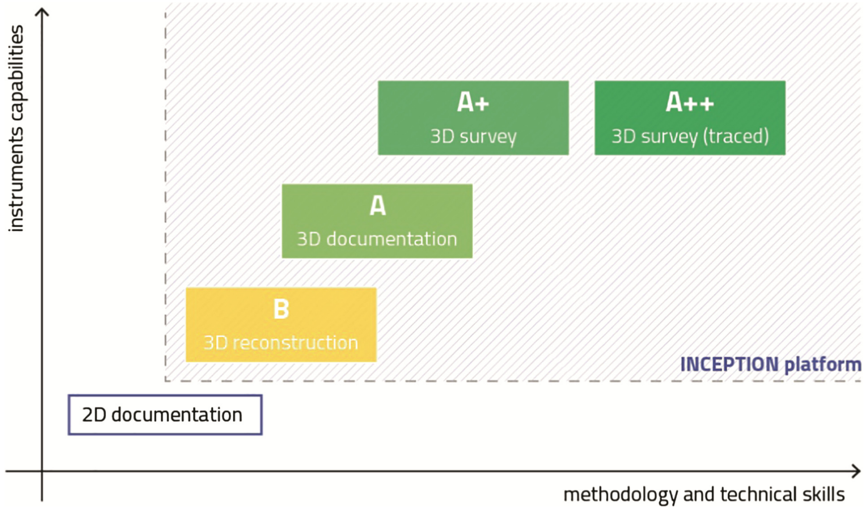

Fig. 5. Evaluation categories.

A+: This evaluation category is most suitable for preservation purposes because only the surveys compliant with this category can be a useful tool for restoration projects that need extremely correct metric data. From this survey, BIM models as well as 2D CAD drawings with 1:20 scale are available. The project phase is more important than previous categories in order to schedule and manage the survey campaign and choose the right technical instruments to perform the data capturing. The management and the correction of metric errors are based on topographic techniques, in particular for what could concern the registration of a different scan. The documentation phase will be developed organizing the information into metadata and paradata [12]. Elements of quality control are integrated into the process.

A++: This evaluation category is suitable for very complex buildings where the capturing process needs to be documented and traced in order to get the maximum control on data or when monitoring processes are developed in a non-continuous time span. The A++ category could be useful even if different teams of technicians work together, simultaneously or in sequence, with different capturing instruments and different accuracies. The A++ category allows the analysis of how a survey has been performed in every single phase: moreover, this capability allows integrating a survey in different times.

A direct correlation between evaluation category and type of building or deployment purposes can be identified. Indeed, complex buildings or advanced deployment purposes need a higher ranked capturing procedure. At the same time, it is necessary to point out that a further standardization should be avoided because every building or site is different from another and there is an increasing number of digital data deployment.

4 Assessment and Added Values by DAP

In order to understand the impact of the INCEPTION DAP, a specific evaluation grid has been set up, starting from the three standard features of quality, time and cost. Each key feature for the evaluation of benefits and added values is specifically addressed looking at the main aims of the INCEPTION project. Since the evaluation process considers the points of view of the end users, who could be either technician or not, features have been developed as below:

- quality can be evaluated as the reliability of the survey;
- time can be evaluated as the usability of the survey;
- cost can be evaluated as the effectiveness of the survey.

Even if the accuracy and the precision are key factors for technicians that are performing the survey, they are strictly connected with the purpose of the survey and for this reason using them for the evaluation of survey quality becomes impossible, in particular from the point of view of an end user. The quality of a survey could be better described as the capability to be compliant with standards and ensure long term support. For this reason, key features of a reliable survey are:

- survey maintenance: possibility to constantly update a survey database during daily use for ordinary purposes, enriching it with new information of minor changes;
- survey integration: possibility to perform major updates and upgrades of a survey, adding a new part of a building or a site previously not included, or performing a more accurate survey of already existing parts;
- tech obsolescence: because the hardware and the data management software are evolving faster and faster, applying strategies to avoid technical obsolescence becomes a key feature to ensure the survey reliability.

The measurement of benefits in terms of time consumption could be performed taking into consideration the usability of the survey. The more usable a delivered survey is, the more time could be saved by the end users that will deal with it. One of the main aims of the procedure is the ability of saving time in the processing phase. The Data Acquisition Protocol and the adoption of a shared standard between suppliers and end users can bring a strong added value in terms of easy usability. For this reason, key features of a usable survey are:

- common procedure: in order to ensure the full understanding of the output;
- collaboration tools: in order for possible data creation by different teams at different times.

The cost of a survey is always dependent on the final quality and time spent to perform the survey. For this reason, the measurement of the effectiveness could be a better parameter to consider in order to evaluate the added value. For this reason, key features of an effective survey are:

- on field flexibility: possibility to use different kinds of instruments on field in order to produce the right amount of qualitative data, without the use of too expensive and unnecessary ones;
- easy deployment: ability to easily use the same delivered survey data for different kinds of deployment and direct application for multiple purposes;
- easy understanding: ability to easily read and understand data delivered with the survey from a low-skilled non-technician end user.

In order to measure benefits and added values by INCEPTION DAP, typical survey and documentation processes in the Cultural Heritage field have been categorized in order to mainly perform a grouping of an infinite number of different, single and specific cases. The main connections between survey categories and DAP evaluation categories have been identified, and the DAP is split in three on the basis of requirements that are needed to reach a better evolution category according to reliability, usability and effectiveness (Fig. 6).

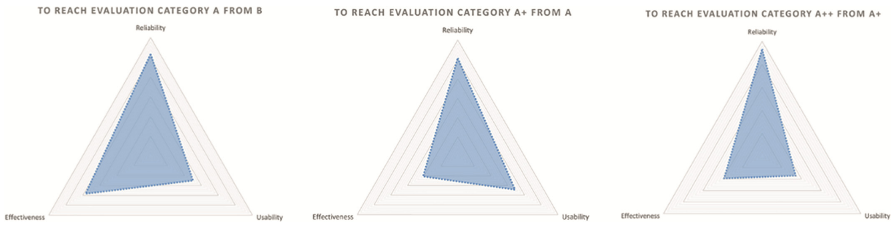

Fig. 6. Data aggregation for the assessment of evaluation categories.

5 Conclusions

The definition of a common framework for documentation and survey of European tangible cultural asset can take advantage by the assessment of the Data Acquisition Protocol. By applying this methodology, it is possible to understand which the main inputs to standardization in 3D data acquisition are. Indeed, it is easy to understand in which direction it is possible to address the standardization process compared to the required benefits.

Thanks to the comprehension of advancement made possible by the protocol adoption, it will be possible, in future developments of this and other research, to focus on the integration of low-end data capturing instruments.

The INCEPTION project shows how the DAP allows us to use the 3D data over time, with different skills, as well as a useful 3D digital data management towards H-BIM [13]. Nevertheless, INCEPTION focuses on open standards like E57 for point clouds and open standard IFC for semantic BIM data managed by Semantic Web-based technology to enable a long-term open access and interrelation of all available data.

INCEPTION innovation in 3D modelling applied to Cultural Heritage starts from the generation of high quality models [14], and therefore from an effective data capturing procedure. The DAP has been developed within a more general methodological procedure of heritage documentation. These guidelines will be gradually developed and updated during the project progress and within future 3D survey application in the field of Cultural Heritage.

Moreover, focusing on needs and requirements of technicians and non-technical users of heritage documentation, DAP assessment increases the benefits to the application of standard procedures in the Cultural Heritage field, starting from the assessment of different types of 3D survey and documentation (features, precision, speed, safety, area or range, environment), results, post processing and usage.

Acknowledgements. The project is under development by a consortium of fourteen partners from ten European countries led by the Department of Architecture of the University of Ferrara. Academic partners of the consortium, in addition to the Department of Architecture of the University of Ferrara, include the University of Ljubljana (Slovenia), the National Technical University of Athens (Greece), the Cyprus University of Technology (Cyprus), the University of Zagreb (Croatia), the research centers Consorzio Futuro in Ricerca (Italy) and Cartif (Spain). The clustering of small medium enterprises includes: DEMO Consultants BV (The Netherlands), 3L Architects (Germany), Nemoris (Italy), RDF (Bulgaria), 13BIS Consulting (France), Z + F (Germany), Vision and Business Consultants (Greece).

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