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A Digital Data Curation-Based Photogrammetric Acquisition Methodology for Cultural Heritage, expanded with CIDOC CRM Compatibility: protocol BeA-PG

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Abstract

The increasing digitalization of cultural heritage assets and the exponential expansion of digital repositories have created new opportunities for archaeological documenting, preservation, and dissemination. Photogrammetry, a survey approach that uses photographic acquisitions to construct highly detailed 3D models of objects, buildings, and landscapes, is one of the most promising techniques in this field. The effectiveness of the photogrammetric process, however, has still limitations due to a lack of experience sharing and data interoperability, which have resulted from the singularities of the techniques in both process and data format.

To address this issue, this paper proposes a novel workflow for the photogrammetric process, called BeA-PG, developed for the BeArchaeo archaeological project. BeA-PG implements two relevant features for improving the effectiveness: on the one hand, sharing is improved by widening the scope of the process representation from the specific archaeological context to the broader cultural heritage context, by adopting the Digital Data Curation process abstraction; on the other, it improves the interoperability by describing the process with a shared ontological vocabulary, namely the CIDOC-CRM model.

The paper introduces the major features of the photogrammetric process, its description through the abstract flow of the Digital Data Curation process, and its encoding through the CIDOC-CRM vocabulary. We illustrate the BeA-PG workflow and its experimental application in the practical setting of the BeArchaeo project.

1. Introduction

Digital imaging technologies have revolutionized archaeological documentation and analysis. From photogrammetry to LiDAR and Structure from Motion (SfM), these methods offer efficient and accurate recording of archaeological contexts, artifacts, and landscapes. They produce spatially-referenced outputs, such as orthophotos and digital elevation models, that facilitate research, digitization, and public outreach. Various digital acquisition techniques are utilized in contemporary cultural heritage analysis, such as Laser Scanners, LiDAR, and ground-penetrating radar. Laser Scanner has proven effective in archaeological structures at construction sites [FFA*16], LiDAR can reveal hidden architectural archaeological information beneath vegetation [SG14], and ground-penetrating radar has the capacity to conduct extensive surveys on archaeological structures, even in urban areas where excavation is impossible [BCN*00].

In digital imaging for archaelogy, there have been some efforts in interdisciplinary settings: the use of unmanned aerial vehicles (UAVs) to rapidly document and analyse built cultural heritage applied to record and interpret two surface water cattle tanks constructed by Texas cowboys in the mid-1880s [HJCFC21]. On the same path the case of the Mouseion Topos, which thanks to the use of the HERMES methodology, has allowed the reorganization of the digital material concerning traditional local settlements situated at three Aegean islands. In the first case, we have a classic example of the use of digital imaging technologies, in the second a representation of the solutions offered in relation to the organization of already produced data [CNV*21].

Photogrammetry, one of the main techniques in digital imaging in archeology, involves the use of specialized software to process photographs or digital images to produce measurements and reconstructions of significant sites, artifacts, and structures

[CLO*10]. While new techniques attempt to bridge various approaches and develop novel solutions [BBFB22, KNT*22], photogrammetry has emerged as the most widely used technique. It's because that photogrammetry is also cost-effective compared to other instruments, such as laser scanners, making it an attractive option for cultural heritage professionals. However, it is a survey technique that is not included in a single instrument but is broken down into various software and hardware components (the camera, processing software, and modeling software) and produces a large amount of data. Consider for example the survey of the Sanctuary

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of the Great Gods on the island of Samothrace, where, even considering the adoption of a specific acquisition protocol, the exact number of photographs is not known but the estimate is around 5000 photographic acquisitions per 1000 square meters of the archaeological site [BPW21]. These numbers tend to increase dramatically to the extent that the archaeological context presents characteristics of strong morphological irregularity or complexity of the elevations.

The vast amount of data generated during the photographic acquisition process needs effective data organization and management to ensure the long-term preservation and accessibility of the data. Metadata on the accuracy of photogrammetric acquisition is critical for the proper interpretation and use of data [Rem11]. Metadata relating to the camera model, the type of lens of the instrument, the processing software used, the point cloud densification algorithm, and the reconstruction algorithm are all important. Although mentioned in the literature, they are often detached from the 3D model and then lost, invalidating the scientific legitimacy of the 3D model. The intrinsic modular nature of the photogrammetric acquisition, in relation to the large amount of data produced, has led scholars to start working on structuring a unique acquisition protocol. To name just a few of the more recent examples Guidi et al.'s work on Donatello's "Maddalena" statue [GBA04]. In this case, we are presented with a detailed description of the technical aspects of acquisition, focusing on specific and irreplaceable instruments. The entire protocol centers around the definition of a specific survey, providing specific details even on the processing and modeling machines for the 3D model. While this path is detailed, it offers no room for generalization and abstraction of the process. Another example is Sebar et al.'s work on an abstract acquisition protocol that outlines defined acquisition paths [SAG*20]. This protocol outlines a sequential approach to survey activities, encompassing acquisition and modeling phases. However, it does not allow for the integration of processes in progress or the inclusion of material from projects that follow different protocols. It is constrained to scanning processes that strictly follow a step-by-step progression, limiting its adaptability to incorporate diverse protocols or ongoing work from other projects.

Although we observe the design of different acquisition and processing protocols that do not share guidelines or lack a unique ontological and formal system that allows for metadata comparison and the challenges regarding interoperability in cultural heritage have already impacted the research field [KFH09] also making it difficult to collect information for those projects whose purpose is precisely to bring together the information collected from different projects, such as the case of the project ARIADNE, an e-infrastructure that integrates archaeological datasets from various institutions and achieves interoperability through the use of controlled vocabularies, thesauri, gazetteers, and ontology [RFG16].

Therefore, if we consider ontology and a modular process marked by fundamental steps for the intercommunication of data and metadata, as well as the importance of creating and adopting a methodology that can be understood both by humanists and computer scientists, it seemed clear to us to turn to already existing and widely shared ontologies, vocabularies and abstractions which could be the basis for structuring the Bea-PG workflow.

The effort to which it tends is in fact that of not creating an acquisition and processing path that works within the research project that generated it but which on the contrary proves to be adaptable to different archaeological contexts and which can also act as a tool of communication and interpretation of existing protocols. For this reason we turned to Digital Data Curation to produce an abstraction of the phases, and to CIDOC-CRM as regards ontology and vocabulary or, more specifically, Digital Data Curation, for standardizing digital processes related to cultural heritage [MSMJ19], and CIDOC-CRM, for providing a shared formal encoding of processes and data, to create a shared database schema [BCG17].

As we are about to illustrate, the working hypothesis of this paper is to develop the description of processes and data for the case of photogrammetric acquisition from these general frameworks. We illustrate here the main tenets of a protocol, named BeA-PG, based on the fundamental assumptions of Digital Data Curation anD CIDOC-CRM models. We start with the abstraction of the photogrammetric case in the sense of the Digital Data Curation, to exploit the constraints and formats that have been developed for the general case of cultural heritage and then provide a formal encoding by exploiting the terms provided by the CIDOC-CRM model. The goal is to make a protocol abstraction that can provide a comparison base for the protocols in the field.

The paper is structured as follows: state of art of general frameworks for photogrammetric acquisition in archaeology, a brief introduction to Digital Data Curation and CIDOC-CRM, the preliminary development of a BeA-PG in the context of the abstraction of Digital Data Curation and the encoding of CIDOC-CRM, and conclusions. This line of research is still ongoing but hopes to be able to allow for the development of a shared formal description of processes and data, creating a shared schematic database.

2. State of the art

Magnani et al. and Howland et al. have analyzed the role of photogrammetry in contemporary archaeology, highlighting its usefulness as a rapid and economical tool for digitization and public outreach. However, despite its widespread use as a visual aid, in both studies, they show how its analytical potential remains underdeveloped [MDS*20]. Nevertheless, photogrammetry advantages, including speed, precision, cost-effectiveness, and adaptability, have made it a successful tool in archaeology. Techniques derived from photogrammetry, such as LiDAR and Structure from Motion (SfM), have expanded its capabilities in creating GIS outputs, while low-altitude aerial photography can facilitate the production of 3D models [CSRG19]. Photogrammetry has also shown the ability to replace outdated or expensive mapping tools, as demonstrated in Clevenger's study [Cle27].

In addition to its advantages, the widespread use of photogrammetry in archaeology and cultural heritage has led to a vast amount of data and raises concerns regarding the management of large virtual archives [AE09]. The storage, structuring, and appropriate management of territorial data obtained through these techniques remains challenging and is limited by the capabilities of spatial database management systems [OEWO19]. As a result, scholars often focus on technical issues related to digital space management, theorizing new solutions for its management, but tend to neglect the theoretical and methodological aspects or place them in a subordinate function to hardware issues [MMF*23]. Such confusion in data set management poses the risk that, once the project producing the data and metadata is completed, the absence of a reusable or compatible ontological storage methodology may result in the abandonment of project data and the subsequent loss of information [FKK*13].

The adoption of standardized formats represents the most effective solution to address the fragmentation of digital archaeological data [KS22]. Standardization allows data to be harmonized and interoperable across multiple platforms, enabling integration and the development of advanced analysis and visualization tools. However, the implementation of standard formats requires a common understanding and agreement within the archaeological community. Nevertheless, the benefits of standardization outweigh the effort required to implement it, offering greater opportunities for knowledge sharing and collaboration in the field of digital archaeology [Zho21]. Recognizing the significance of abstract methodologies in developing photogrammetric protocols, we propose that an ontology-driven and methodologically grounded protocol can serve as a valuable tool for both new and existing projects. Such a protocol would encompass common categories found in other workflows and provide a framework for incorporating specific terms from different contexts into a shared ontology. By embracing a shared ontology, protocols can extend beyond their original scope and effectively address the semantic construction of protocols, as demonstrated by the Inception Protocol. This approach not only offers a functional tool for project implementation but also promotes coherence and interoperability across diverse photogrammetric workflows. [GMP*17]. Other projects have focused on specific protocols for particular categories of objects [RMRG20], while some research has not focused on structuring a protocol but on evaluating acquired three-dimensional models [NMR14]. These protocols, subjected to a verification and recognition of the shared substantial contents hidden under the surface of a formal difference, could communicate with each other.

3. Abstract models and the application to photogrammetry

As we have observed, in the context of digitalization in archaeology, it is crucial to have a more shared view at some abstract level, even up to employing a standardized vocabulary. The abundance of data generated by digital technologies presents challenges in managing large archives, leading to the risk of losing valuable information if there is no standardized methodology for archiving and managing data. Using an ontological and methodological approach can offer not only a functional tool for new projects but also provide a framework for integrating previous protocols developed in other projects. By adopting a shared vocabulary and ontology, we can ensure compatibility and coherence between different projects and facilitate the reuse of data. Therefore, a common vision and a standard vocabulary and ontology are essential for advancing digitalization in cultural heritage, enabling a more comprehensive understanding of the objects and their contexts. In order to provide a shared vocabulary we need first to produce an abstraction from the specific approach and describe it in some general terms. This is why we have approached Digital Curation framework.

Digital Data Curation is the practice of managing, preserving, and adding value to digital data throughout its lifecycle. This involves ensuring that data is stored in a secure and accessible manner, while also adhering to ethical and legal obligations. Curation activities may include organizing and describing data, selecting appropriate storage and backup methods, creating metadata, and ensuring long-term preservation through digital archiving [Hig08]. The field of Digital Data Curation has become increasingly important as the amount of digital data produced continues to grow rapidly, particularly in the context of cultural heritage institutions. Digital Data Curation requires a deep understanding of both the technical and scholarly aspects of the data being managed, as well as a commitment to ensuring that the data remains usable and accessible over time. Despite the success of Digital Data Curation, only a few projects in photogrammetry make reference to it [LL23]. Among these, we can cite the CulTO project, which refers exclusively to religious architectural structures [GMS*17]. Generally, with few exceptions [KLD*20], Digital Data Curation is not a reference for the digital archaeological field. In 2019, Fernandez wrote about the relationship between photogrammetry and digital curation, referring to it as a "Digital Drama" [Fer19].

On the other hand ontologies and thesauri play a fundamental role in the development of shared terminological vocabularies for digital databases in various domains, including cultural heritage. These tools provide a standardized and structured approach for organizing and defining the concepts and relationships within a particular domain, enabling a more efficient and effective search and retrieval of information from multiple sources. The CrossCult project, funded by the EU, uses semantic technologies to model and semantically link disparate pieces of cultural heritage information, aiming to change the way European citizens appraise history [VBKM*17]. Freire et al. assess the usability of ontologies by crawlers operating on the data web [FdV19], while Doerr's reflection attempts to represent and define ontologies in cultural heritage from a point of view of classification and absolute ontological value [Doe09]. Because the use of ontologies and shared vocabularies has the potential to facilitate interoperability, data integration, and data reuse, which are crucial for the preservation and dissemination of cultural heritage great effort has been devoted to the development of these shared ontologies and vocabularies. That commitment has led, in the field of cultural heritage, to the creation of the CIDOC Conceptual Reference Model (CRM) that has emerged as the main reference ontology for the management of databases and information in cultural heritage [BCG17]. This ontological model for cultural heritage data has been developed by a specific committee of the International Council of Museums (ICOM). It provides a formal structure for describing and linking cultural heritage information, such as objects, events, actors, and their relationships. The CRM is a high-level ontological model that provides a common vocabulary and a framework for integrating data from different sources, enabling interoperability and data exchange between different systems. It is designed to be domain-independent, flexible, and extensible, allowing the modeling of complex cultural heritage information. CRM is widely used in the cultural heritage domain and has been adopted by many insti-

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tutions and projects worldwide. It is continuously maintained and updated by the CIDOC CRM Special Interest Group, which ensures its relevance and adaptability to new challenges and requirements in the field of cultural heritage [BCG17].

While the CIDOC-CRM has been used in previous archaeological projects, these have been limited to highly specific cases. For example, the GROPLAN CIDOC-CRM is employed to increase compatibility with the Java programming language [BCG17]. The VENUS European project also utilized the CIDOC-CRM to structure ontology for training an artificial intelligence in underwater photogrammetry [DMH*15]. In both cases, we observe an exceedingly specific utilization of CIDOC-CRM, maintaining a high level of class, domain, range, and property usage. However, the focus is excessively limited to the particular use case, rendering the abstraction intended for method transmission impracticable at this level. Despite the theoretical emphasis on cultural heritage and the existence of initial efforts to implement the CIDOC-CRM in a holistic vision that addresses ontological needs and overcomes practical obstacles in organizing digital data within a project [LKG*22,LDKM20], research on the application of CIDOC-CRM in relation to photogrammetry has predominantly remained abstract. There is a lack of established position that bridges the gap between specific protocols and the broader theoretical application. It is necessary to develop a framework that mediates between the theoretical foundations of the CIDOC-CRM and the practical challenges encountered in organizing digital data, in order to effectively utilize this tool in photogrammetric applications [CSPD10]. In conclusion, there is a need for a more balanced approach that considers both the theoretical and practical applications of the CIDOC-CRM in photogrammetry.

4. BeA-PG workflow and CIDOC-CRM encoding

The BeA-PG workflow is a photogrammetric acquisition method designed for archaeological object surveying. Developed in the context of the BeArchaeo project, it comprises five main phases: Acquisition, Processing, Modelling, Exporting, and Archiving, each further divided into subphases that detail the methodological actions to be taken for successful completion (Figure 01). The pre-archiving system, which generates a unique code for each 3D model, involves creating a folder structure that includes folders for photographs and model data. The entire protocol is built upon the logical categories established by Digital Data Curation, and although not identical in name, the two systems overlap to a significant extent. Efforts are currently focused on making the BeA-PG model encoded with CIDOC-CRM. While the protocol has been used in specific contexts, such as the archaeological project BeArchaeo, its implementation is highly adaptable and can be applied in diverse contexts to enhance the accuracy and completeness of archaeological surveys. The ultimate goal of the BeA-PG protocol is to improve data interoperability and promote collaboration across diverse projects.

The BeA-PG protocol was initially conceived with a phased structure that aligns with the ontological representation of entities, ensuring compatibility with the CIDOC-CRM vocabulary. The emphasis was placed on identifying intersections between the original framework and the classes and entities provided by the CIDOC

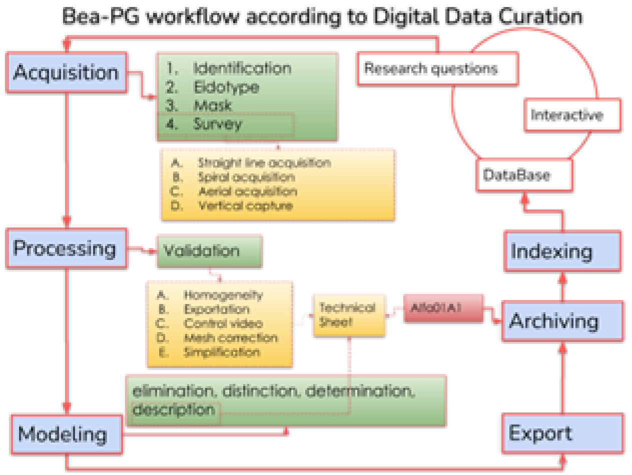

Figure 1: *Representation of the general scheme of BeA-PG. The main phases are distinguished: Acquisition, Processing, Modeling, Export, and Archiving*

CRM, facilitating seamless integration. The central focus of the scheme is the E24 Physical Human-Made Thing, which represents the archaeological object and the 3D digital model. The survey activity, referred to as E12 Production, acts as the intermediary between the physical and digital representations of the archaeological object. To fully understand the scheme, it is essential to appreciate its expanding nature. The production of the survey can be broken down into various activities, including acquisition, processing, modelling, exportation, and archiving. Each of these activities produces physical components of the 3D model. These components comprise the Texture, Point Cloud and Mesh, all of which are also expressed as E24 Physical Human-Made Things. However, the scheme is designed to describe a unique case, that of an individual archaeological object. A process of abstraction becomes necessary to move from the production of a single object to the acquisition protocol, which is expressed as an E29 Design and Procedure (Figure 02).

In order to accurately classify and analyze operational subphases, it is necessary to establish a connection between these subphases and their corresponding. Typologies for this reason the protocol was re-designed to identify commonalities between the original scheme and the classes and individuals offered by the CIDOC CRM, with a focus on the E24 Physical Human-Made Thing, which represents both the archaeological object and its corresponding 3D digital model. The E12 Production serves as a vital intermediary in the protocol, facilitating the conversion of the archaeological object into a virtual representation, the 3D model. This transformation not only makes the 3D model an integral part of the protocol but also establishes it as a virtual manifestation of the original archaeological object. The decision to assign the 3D model the status of a Physical Object rather than an Information Object was carefully considered. Within the BeA-PG protocol, the 3D model serves a functional purpose that requires it to be treated and managed based on broad and complex properties, which would be limited if considered solely as an Information Object. Moreover, in the context of manipulating the 3D model, it is more practical and functional to treat it as a Physical Object rather than an Information Object. In fact, the CIDOC manual itself suggests treating virtual objects as Physical Objects since they are human-made.

The BeA-PG production process is broken down into various activities, including acquisition, processing, modeling, exportation, and archiving, each producing physical components of the 3D model, such as Texture, Point Cloud, and Mesh, which are also expressed as E24 Physical Human-Made Things.

However, the protocol is designed to describe a single case, that of an individual archaeological object. Abstraction becomes necessary to move from the production of a single object to the acquisition protocol, which is expressed as an E29 Design and Procedure.

To accurately classify and analyze operational sub-phases, it is essential to establish a connection between these sub-phases and their corresponding. Typologies, as expressed in the E55 Type property. This can be achieved through the use of the "P67 refers to" property, which enables the relocation of each protocol phase with each previously described activity. The relationship between E7 Activity, P2 Type, E55 Type, and E29 Design and Procedure allows each activity to be classified based on its corresponding Typology and designated a specific sub-phase in the overall procedure.

The establishment of clear and concise connections between sub-phases and Typologies is crucial to ensure accurate identification and classification of each phase and activity. The CIDOC has demonstrated its effectiveness in accurately defining the temporal relationships between different stages and sub-stages, which is crucial in the development of 3D models using the BeA-PG photogrammetric acquisition protocol. This allows researchers to discern interrelated stages and sub-stages and identify crucial dependencies required for progression. The temporal scan is also vital for identifying phases that follow a logical but not necessarily sequential relationship and those that are strictly sequential in nature.

The CIDOC thus plays a crucial role in facilitating thorough research and the effective development of sophisticated 3D models. Figure 02 provides an overview of the protocol, while Figure 03 depicts the relationship between E7 Activity, P2 Type, E55 Type, and E29 Design and Procedure. Figure 04 and Figure 05 illustrate how the CIDOC accurately defines temporal relationships between different stages and sub-stages, providing researchers with a comprehensive understanding of the complexities and nuances of the 3D model being produced. Specifically, we observe how the archaeological object (Archaeological Object 01) undergoes the Survey process, resulting in the creation of the 3D model (Physical Human Made Object). The 3D model is then decomposed into its physical components, namely the Texture, Mesh, and Point Cloud. From there, we can examine how these components are generated through the various phases of the protocol, which are represented

in Figure 01 but categorized according to the classes and properties of the CIDOC CRM (Figure 02 and subsequent).

5. Application of the BeA-PG methodology and the CIDOC CRM in a case study: project BeArchaeo

We use them to represent a case study extracted directly from the BeArchaeo project. The Be-Archaeo project focuses on the archaeological excavation of the Tobiotsuka Kofun in Soja City, Okayama Prefecture, along with the study of other Kofun burial mounds and related archaeological material in the ancient Kibi and Izumo areas (present-day Okayama and Shimane Prefectures). The project aims to explore rituals, regional relationships, and the formation of ancient states in Japan. Collaborating archaeologists from Europe and Japan, together with a diverse team of archaeometry experts (including chemists, physicists, biologists, geologists, petrographers, veterinary surgeons, and soil scientists), conduct advanced research on this significant period of Japan's early history.

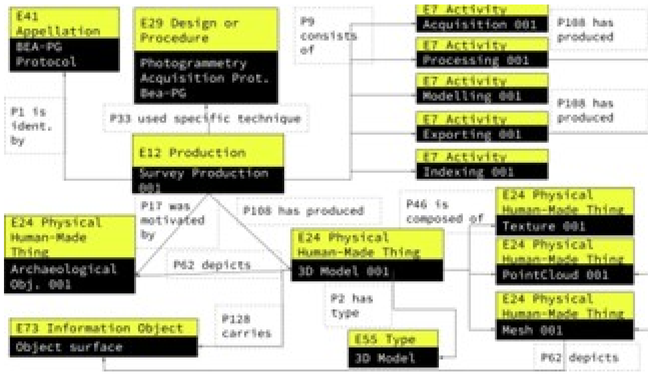

Figure 2: *Regarding the relationships between Specific archaeological objects, Specific activities and Design Procedure. In this slide, we illustrate the differentiation between archaeological artifacts, surveys, and derived 3D models using CIDOC ontologies and vocabularies. We define the digital components that make up the model and clarify their derivation from procedural phases.*

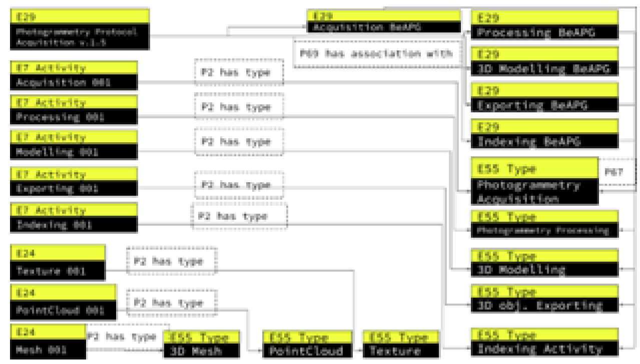

Figure 3: *Regarding the relationships between design phases and types of activities. This slide illustrates the connection between the material nature of classes and the protocol phases, emphasizing the typological relationship between each phase and its specific case, while also paving the way for its abstract definition.*

Within this project, a considerable amount of archaeological artifacts from the Okayama area and the Tobiotsuka site needed to be photogrammetrically recorded. The 3D models generated constituted part of the metadata, combined with archaeometric analyses and observations from archaeologists, which were then incorporated into the Omeka-s database. Additionally, a portion of the

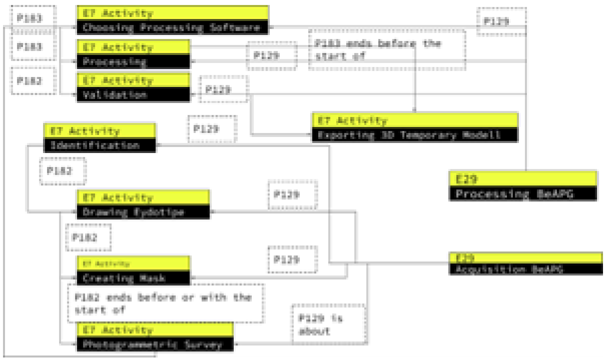

Figure 4: *Regarding the activities indicated by the individual procedures and their temporal relationships for Acquisition and Processing. To maintain general applicability, the preliminary phase avoids specific dependencies on the 3D model product. Instead, it focuses on defining subclasses of procedures, as shown in the initial BeA-PG structure diagram (Figure 01), while disregarding subclass details at this stage.*

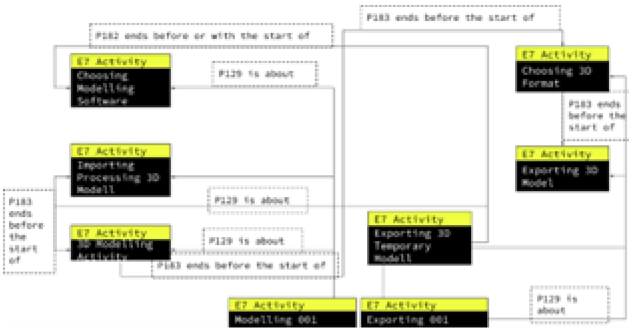

Figure 5: *Regarding the activities indicated by the individual procedures and their temporal relationships for Modelling and Exporting*

produced 3D material was integrated into the interactive Bea-Vir exhibit, showcased at the Izumo Museum in October 2022. The interactive content was subsequently converted into a browser-based project compatible with VR and AR tools. Hence, considering the dispersed nature of the artifacts across various institutions in Japan, 3D surveys played a crucial role in studying, classifying, and organizing the artifacts, alongside the necessary development of the Bea-PG workflow.

Specifically, this case study pertains to the artifact classified in the project's database as AF MNM 005, which consists of a manipulated wild boar jaw from the Yayoi period unearthed at the Minamikata site in Okayama. The 3D model of the jaw was generated following the BeA-PG methodology, enabling us to trace all the generative phenomena of the 3D model deduced from photogrammetry: Name, Type Reference culture, Position, Acquisition date, Internal Classification, Software, Number of points, Algorithm, Operator. This is the information reported in the BeA-PG protocol's card. Simultaneously, we have the data stored in the database that refers to the same artifact, providing us with the following information: Description, Archaeological

Finding Record, Object definition, and directly related object, initially found in, chronology.

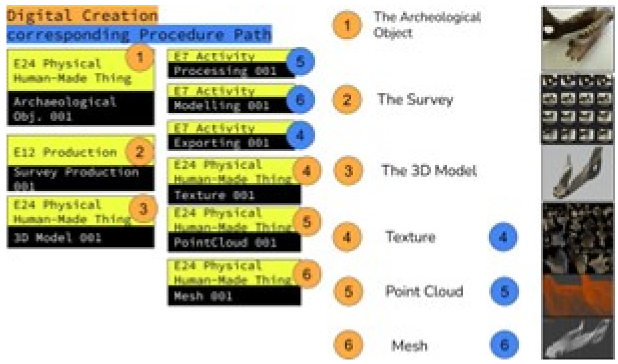

Figure 6: *How the photo detected find and the resulting 3D model are broken down into the various classes and individuals of the CIDOC-CRM. The same categories will then flow into the reference database.*

Currently, a copy of the card that is present in the database can be used to access the information on the BeA-PG protocol's card via an interlink that is present in the database card. In addition to making the data more readily accessible, the coincidence between the BeA-PG protocol and CIDOC CRM aims to archive and store more data in an organic way, enhancing the archival fusion between the BeA-PG protocol's output and the data kept in the Omeka-S-based database. In order to assess the outcome, we have therefore retrieved the schema created thus far and added the AF MNM 005 artifact to it.

5.1. The BeA-PG protocol applied to other protocols

One of the most important aspects of the BeA-PG protocol is that it does not seek to replace other protocols designed in different contexts, but rather to function as a means of communication with other significant protocols in order to increase interoperability and contribute to the enrichment of the metadata they produce, with a view to the eventual integration of the information into a coherent database. The case of Colonia Dacica Sarmizegetusa by Adriana Antal et alii [ABC*16] presents itself as an acquisition protocol focused on the final rendering of three-dimensional models in the context of an interactive virtual presentation for a museum. By applying the BeA-PG protocol, we can begin with the interactive itself (which is situated in the Archiving phase as the endpoint), deconstruct the implementation process, and break down all the various parts that make up the interactive, cataloging the 3D models and breaking them down into their essential parts, such as texture, mesh, and point cloud, and associating them with the informative metadata present in the final interactive. From the various components, the production processes of the models will be deduced, thus returning to the base of the Acquisition phase and merging a new organic arrangement of all the material related to this project into a database that communicates with the CIDOC-CRM, thereby allowing the project to obtain all the systematically produced original information. In the case of the Inception Protocol [GMP16], since it is already a sequenced protocol for phases aimed at digital acquisition, we can imagine an ontological coincidence between the various phases of the Inception Protocol and those of the BeA-PG protocol in order to achieve adaptability to CIDOC and thus to a possible final database. Action 01 of the Inception Protocol (Common Framework for cataloging methodology) coincides with the first sub-phases of the Acquisition phase, which are of an analytical nature, and already in this first phase, we can organize reconnaissance and other speculative activities on the artifact so that the metadata produced, from the acquisition path to the actual acquisition, are organized while imagining the Space and Time factors already provided by the Inception Protocol to which we add the Typology voice provided by the BeA-PG protocol's archiving. As for Action 02 (Integrated data capturing), it converges in the second group of sub-phases of the BeA-PG Acquisition phase, distributing and organizing not only the data and metadata derived from the actual survey and potential analyses of the archaeometry on the artifacts but also punctually managing the *consecutio temporum* of the survey phases. At this point, Action 3 (Semantic Model for cultural heritage) no longer becomes a detached process but is pre-announced by the preceding phases, with all the data prepared for their insertion into a semantic database and following step by step the Elaboration phase, guiding the manipulation of the model in the Modeling phase and in which each step is recorded, thus directing it towards Action 04, which is no longer the insertion into an Inception platform but a broader database based on the principles of CIDOC-CRM and thus communicable with any database of the same type, preserving this relationship between data and metadata even in the final Archiving phase in which both Action 04 and Action 05, Deployment and Valorization, coexist. Ultimately, the comparison and application of the Bea-PG workflow in relation to the Inception protocol demonstrate that there is no need to envision a specific ontology for each project or invent a separate ontology for digital surveys. The shared ontology and vocabulary are already embedded within the Bea-PG survey protocol. This organization of ongoing materials showcases the potential of utilizing the Bea-PG workflow to establish communication with other existing protocols and methodologies.

6. Conclusions

In conclusion, this paper presents an experimental encoding of photogrammetry for digital documentation, preservation, and dissemination of cultural heritage assets. The BeA-PG workflow aims to represent the process in the specific archaeological context and extend it to the broader cultural heritage context using a shared ontology, particularly the CIDOC-CRM framework however always taking into account the conceptual guidance provided by Digital Data Curation serves as a methodological and conceptual guide for the entire protocol.

The case study demonstrated the effectiveness of the BeA-PG workflow in decomposing every single component of a photogrammetric survey of an object and preserving all related metadata, which can lead to new data and sources of inspiration for big data

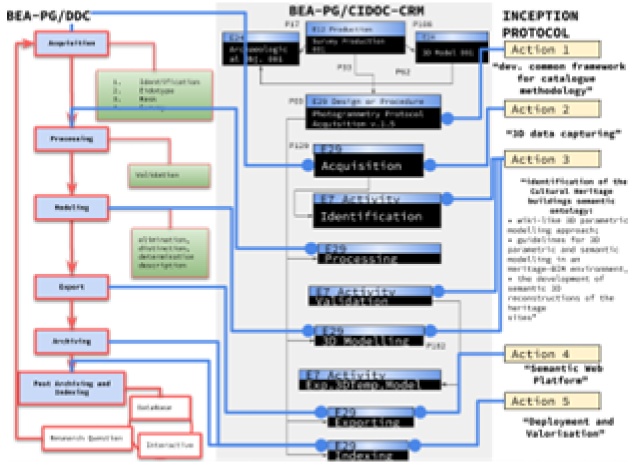

Figure 7: *Schematic and summary representation of the recognizable coincidences between the Bea-PG workflow and the Inception Protocol through the classes offered by the CIDOC-CRM organized according to the Bea-PG phases*

management. This method has been shown to reconcile time and cost needs with survey activities and facilitates interoperability and sharing across several photogrammetry protocols, enabling the integration of data from various sources. The BeA-PG workflow provides a promising approach to photogrammetry and contributes to the efficient digital documentation and preservation of archaeological assets. In the next future, we are going to validate the workflow in further projects and yield a stable version of the protocol, to be widely applied to the large realm of archaeological projects.

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