SEMANTIC BRIDGING OF CULTURAL HERITAGE DISCIPLINES AND TASKS

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Abstract. Cultural Heritage (CH) domain encloses a wide range of different disciplines, serving preservation of objects, collections, sites and dissemination of knowledge. In this context, stakeholders of different sciences generate, retrieve and share a vast amount of diverse information. Therefore, the information interoperability has been considered as a crucial task, especially in terms of the semantics. In this direction CIDOC Conceptual Reference Model (CRM) has been widely used for the matching and merging of related to the CH domain ontologies and metadata standards. Additionally, it has been the base for extensions development in order to meet the needs of specialized fields and tasks. Nevertheless, an aggregate table or a conceptual map which could clarify the correlations between the different ontologies and schemas is not yet defined. Our study includes the review of relevant existed approaches and the proposal of a conceptual layering, considering the CIDOC CRM and its individual models as the centre of the organization. Matching and alignment to this high-level ontology is an elaborate task due to the differentiation of abstraction levels and fields of interest. This work could further clarify the semantic level and focus of the different ontologies and schemas, define the scope and method of their combination according to the separate needs of a domain or task, as well as the identification of semantic lack for specialized CH activities and fields. Eventually, we will outline the efficient combination of different ontologies and schemas, aiming to the best possible capturing of information provenance.

Keywords: Metadata and Ontologies, Cultural Heritage Documentation, Disciplines and Tasks, Review

1 Introduction

Study and preservation of Cultural Heritage (CH) requires the collection, storage and processing of diverse information which are related to different disciplines and activities included in the domain. Furthermore, the combination of these heterogeneous data and the interconnection of different sources are considered indispensable, though not trivial, to accomplish. In this direction, services such as unified management, search and retrieval of cultural content, as well as data integration, data mining and knowledge extraction benefit from semantic web technologies (Häyrinen 2010). Particularly, top-level or core ontologies could define basic concepts and their relations, which are common between different domains. The included entities could be extended with more specific terms of sub-domains, while facilitate the mapping of knowledge representations and metadata schemas between different domains and tasks. CIDOC Conceptual Reference Model (CIDOC CRM) presents a core ontology for the CH information which may stands as global schema, query mediation, guideline for conceptual modeling and information systems or tagging schemes development, being valuable for the organization and use of cultural information (Doerr, Hunter and Lagoze 2006).

Therefore, the review and organization of existed approaches related to CIDOC CRM merging, mapping and extension, as well as their potential conceptual correlation is considered beneficial. In the remainder of this paper we first identify and define the different fields of interest and abstraction levels of cultural heritage information based on research projects of the domain which have used CIDOC CRM (Section 2). Thereafter we present publications and works related to the merging, extending and mapping of the CIDOC CRM (Section 3), while we describe a possible combination and further development (Section 4). Finally, we conclude with a brief discussion of our observations and future work regarding the conceptual representation and data semantic interoperability of the domain (Section 5).

2 Cultural Information Fields of Interest, Factors and Media

The domain of CH embraces a number of sciences such as museology, library and archival science, preservation science, archaeology, architecture, history of art, geoinformatics and chemistry. Considering the differentiation among the aspects that domain disciplines focus on, it is easy to perceive the particularity of cultural information. Even if the different sciences are connected and complement each other, there is a distinction between their approaches and aims. Therefore, the accurate documentation of respective scientists and professionals' observations, conclusions and applied tasks may require different level of detail and focus particularly on different fields of interest.

However, there can be identified a number of common activities and processes between CH sub-domains. These may include scientific observation, analysis and diagnosis, dating, conservation treatment, multimedia production, visualization, digitization, information provenance and scientific inference/reasoning. It is important to mention that according to different disciplines and procedures, the requirement for the way of information recording may differ as well. More particularly, the documentation can be analytical or brief. In this context the modals used may include text with the form both of narrative description or checklist, images, 2D designs, 3D models, diagrams, video, audio etc (Hunter 2002). Additionally, a prominent feature of cultural information is related to the factor of time. Particular features of objects, collections or monuments are not always known, an issue that arises with the incompleteness of the past. Since the study of tangible and intangible cultural heritage and past human activities and events is a constantly evolving process, it is a common phenomenon that information is known or even modified in different points of time (Doerr 2003). Furthermore, there are changes during the time caused by deterioration processes, aging, handling, treatment, environmental factors and so on, a fact that entails the perpetual production and management of new data.

Given the diverse fields of interest and tasks, the multimodality of the documentation, and the continuous data updating on CH domain, it is obvious that there is the need of semantic interoperability between the cultural data. To this aim CIDOC CRM can be perceived as the "semantic glue" which connects the heterogeneous material (Häyrinen 2010). Since today, there is a significant number of research projects which have used CIDOC CRM for the cultural data and sources integration and semantic querying/retrieval (Carlisle, Avramides, Dalgity and Myers 2014, Bruseker, Carboni and Guillem 2017, Niang et al 2017). These approaches indicate the capability and range of CIDOC CRM implementation in CH sub-domains and activities, confirming at some point the aforementioned categorization of included sciences, tasks, documentation media and organizational requirements (e.g. according to time and space). Moreover, research projects and relevant publications propose different cases of CIDOC CRM mapping and merging with metadata schemas or ontologies, as well as its extension for specific information needs, valuable for future work on knowledge representation and management of the domain (Section 3).

3 Merging, Mapping and Extending CIDOC CRM

Reviewing the publications related to CIDOC CRM's implementations in the domain of CH, there were discerned some interesting cases of its mapping with metadata standards and ontologies, its merging with ontologies and its extension with thesaurus, special terms and relations. To thoroughly present and organize the different approaches, the latters are categorized based on the identified disciplines and tasks (Section 2) as it seems in the aggregation table (Table 1).

3.1 Related Approaches and Projects

First things first, a number of compatible models have been developed since today and proposed by CIDOC CRM Special Interest Group, extending its main entities and thus defining more specialized concepts. Official CIDOC CRM family models include CRMsci,CRMinf, CRMarchaeo, CRMba, CRMdig, CRMgeo, and their development and potential implementation is overall presented on Bruseker G., Carboni N. and Guillem A. (2017) recent publication. Additionally, the compatible model FRBRoo is the result of FRBR ('Functional

Requirements for Bibliographic Records') and CIDOC CRM merging. Today, as a CIDOC CRM extension represents semantics about bibliographic information and facilitates integration, mediation and interchange between bibliographic and museum information (Doerr 2009). Accordingly, PRESSoo is FRBRoo' s further extension which captures semantics of bibliographic information about periodicals (CIDOC CRM Family Models and Collaborations). Nevertheless, since these models were gradually published and approved by the community they have not always been included in different CIDOC CRM extension, merging and mapping projects through the years.

Some of the first CH domains on which CIDOC CRM was applied, was library and archival science. In this context, metadata standards, used by Library community such as Encoded Archival Description (EAD) and Dublin Core (DC), have been mapped on CIDOC CRM. As presented by Theodoridou M. and Doerr M. (2001), EAD Document Type Definition (DTD) standard for archival finding aids coding was mapped to CIDOC CRM Version 3.0 in order to define the conceptual equality between the entities of the two standards. Furthermore, EAD has been mapped with CIDOC CRM (Stasinopoulou et al 2007), creating metadata paths and conceptually equivalent CIDOC CRM entities and relations paths, while some new classes and properties were added. On the other hand DC, a metadata standard, used on the domain of library, archival science and CH sector, has been mapped on CIDOC CRM. As mentioned on (Kakali et al 2007), the whole process of DC metadata paths and respective CIDOC CRM paths contributed to the organization of DC values. In the same context, ABC ontology, which facilitates bibliographic information exchange and integration, has been mapped with CIDOC CRM concepts in order to bridge and connect CH and library information. (Doerr, Hunter and Lagoze 2006). This coherent wider model would be valuable for the integration or unified source searching for the two different domains.

Moreover, CIDOC CRM has been exploited in archeology domain for metadata mapping and data integration. According to (Felicetti et al 2013) the Italian Central Institute for Catalogue and Documentation (ICCD) was successfully mapped to the CIDOC-CRM. ICCD establishes a national catalog of Italian cultural heritage. In a similar way, the mapping of the International Core Data Standard for Archaeological and Architectural Heritage (CDS) to CIDOC CRM was carried out during the creation of the Arches system (Carlisle et al 2014). Additionally, an extension of CIDOC CRM for the better definition of archaeological periods and chronologies was presented during the STAR project (Binding 2010). Although there are textual or numerical data which refer to time periods in archaeology and which can be organized using controlled vocabularies, this is not enough to facilitate inference unless the time relations are fully described. Consequently, CRM-EH was developed as an extension of CIDOC CRM that covers the work of excavation and analysis (Binding, May and Tudhope 2008). The model was then combined with controlled vocabularies and treasures that were transformed into SKOS to define concepts and correlations between terms of periods and chronologies.

CIDOC CRM has been proved significantly useful for the knowledge representation on the domain of CH conservation and restoration. Firstly, OPPRA ontology (Ontology of Paintings and Preservation of Art) has extended CIDOC CRM and merged entities of chemistry ontologies, such as OreChem and OIA-ORE, in order to cover the needs of paintings conservation and material analysis (Odat 2014). In the same direction, to cover the requirements of non destructive analysis and diagnosis methods of artworks during the conservation processes, has been proposed a number of terms which extend CIDOC CRM (Vassilakaki, Zervos and Giannakopoulos 2015). Additionally, the analysis of artworks material has been the main subject of CIDOC CRM extension with a thesaurus of relevant terms according to Platia et al. (2017) publication for Polygnosis platform. In this case CIDOC CRM has been the backbone for thesaurus development and terms organisation, extending four basic entities to more specialized terms.

Nevertheless, conservation and restoration domain embraces a wide range of process and respective data that other approaches such as CORE and PARCOURS ontologies have tried to represent respectively, using CIDOC CRM as the core of new classes' organization. CORE (Conservation Reasoning) ontology extends CIDOC CRM with concepts and relations about materials and techniques, condition state and conservation processes of artworks, and particularly byzantine icons (Moraitou, Kavakli 2018). Furthermore, PARCOURS ontology (Niang et al 2017) models information about cultural objects, phenomena and events features, data related to scientific study and included instruments, and information about applied treatments. Similarly to the aforementioned cases, PARCOURS extends CIDOC CRM and CRMsci, defining new and more specialized entities and relations between them, while it integrates different thesaurus of the domain.

Due to the connection between cultural and spatial information, geography is often included in CH domain studies and researches. As has been already mentioned, CRMgeo model covers the needs of geoinformation and its correlation with CH. On top of that, there has been published an interesting approach (Chalkias, Vradis and Kokla 2017), suggesting the extension of CIDOC CRM for the representation of maps elements. Historical maps are perceived as cultural objects, an aspect which is efficiently expressed by the entities and relations of CIDOC CRM. Nevertheless there are some data on every map such as the scale, spatial reference system, orientation etc., which require the extension of CIDOC CRM. This extension may be defined as a cartographical ontology which includes concepts related to maps, graphic elements and symbols.

Cultural data is not consisted of only textual information, but also of various types of multimedia. Although there are metadata for organizing and managing multimedia objects and corresponding models, there is no model for describing museum multimedia content. Therefore, many works have tried to integrate and map the multimedia content standard MPEG7 and CIDOC CRM, such as the one mentioned in the publication (Hunter 2002). Thus the integration of the two models was equally capable of modeling and sorting information about the sources of multimedia content, utilizing the CIDOC CRM as a top-ontology. Moreover, a mapping model of MPEG7 to CRM CIDOC (Angelopoulou, Tsinaraki, Christodoulakis 2011) is presented, allowing the exploitation of multimedia content annotations from digital libraries of CH. Additionally, mapping between CIDOC-CRM and VRA Core 4.0 is presented in (Gaitanou, Gergatsoulis 2011). VRA Core 4.0 is a metadata scheme used by the Heritage Community, originally created by the Visual Resources Association's Data Standards Committee. It provides guidance for describing works such as paintings, statues or other artistic creations, images of visual representations of a work, and collections of groups of works or images. Finally, Messaoudi et al (2018) proposed a domain ontology model mapped to CIDOC-CRM for the reality-based 3D semantic annotations of building conservation states, which takes into account both qualitative and quantitative aspects of a historical building by merging three specific dimensions (semantic, spatial, morphological), bridging efficiently conservation science and information visualization.

Furthermore, CIDOC-CRM has been used in visualizing knowledge of the CH domain. CULTO is based on CIDOC-CRM and is a tool for retrieving and sorting photographic material and text files from historical and religious buildings to preserve and enrich the information that accompanies these buildings (Garozzo et al 2017). Meanwhile, during the projects Labyrinth and Invisibilia, the Archetype ontology was created, which extends CIDOC-CRM in order to visualize the stories characterizing an artwork (Damiano et al 2014). Anh Tran and Isemann present an extension of CIDOC-CRM aimed at defining the relationship between the historical artworks of the Dutch Renaissance (Tran and Isemann 2017). Also, during the DOREMUS project, an extension of FRBRoo model, itself an extension of CIDOC CRM, was created allowing the description of musical works and their publications, concerts, festivals, and recordings that are part of the activities of Radio France and the Philharmonie de Paris (Lisena et al 2018). Finally, OntoMP ontology is an extension of CIDOC which extracts useful information from an extremely heterogeneous set of data including user interviews / narratives, aiming at the implementation of a virtual environment (Araújo et al 2018).

Eventually, considering the information provenance and the development of research infrastructures which gather and integrate heterogeneous data sets, the ongoing PARTHENOS project suggests CRMpe compatible extension (Bruseker, Doerr and Theodoridou 2017.). PARTHENOS entities model is based on the analysis of data structures of the participating registries and extends the CIDOC CRM. CRMpe aims to provide a common expression among the various sources and ensure that produced data of heterogeneous forms will have a semantic re-expression which facilitates their interoperability with other datasets.

Table 1 Aggregation table about merging, mapping and extension approaches of CIDOC CRM, as presented in Section 3.1.

Description	Type	Discipline	Task	Year
Mapping from the EAD DTD Version 1.0 Element Set to CIDOC-CRM	Mapping	Library & Archival Science	-	2001
Encoded Archival Description (EAD) and Dublin Core (DC) metadata mapping to CIDOC/CRM	Mapping	Library & Archival Science	Scientific observation, analysis, diagnosis	2007
Mapping a Dublin Core to CIDOC CRM	Mapping	Library & Archival Science	-	2007
ABC and CIDOC/CRM ontologies merging	Merging	Library & Archival Science	Information provenance, Multimedia Documentation	2006
Mapping the Italian archaeological documentation system to CIDOC-CRM	Mapping	Archaeology	Documentation, Scientific observation, analysis, diagnosis	2013
Arches project - Mapping CIDOC - CDS to CIDOC-CRM	Mapping	Archaeology	Scientific Observation, Analysis and Diagnosis, Multimedia	2014
STAR Project Ontology implements archaeological time periods using CIDOC CRM and SKOS	Extension	Archaeology	History Dating	2010
CRM-EH - a CRM extension covering the archaeological excavation and analysis workflow.	Extension	Archaeology	Scientific Observation, Analysis and Diagnosis	2008
Ontology of Paintings and PReservation of Art (OPPRA) develops, curates and shares controlled vocabularies	Extension	History of Art, Chemistry, Preservation Science	Conservation treatment, Scientific Observation, Analysis and Diagnosis	2014
DOC-Culture Ontology defines the conservation interventions and analysis methods performed on artifacts	Extension	Preservation Science	Conservation treatment, Scientific Observation, Analysis and Diagnosis	2015
Polygnosis platform - a CIDOC CRM extension about conservation and laser technologies	Extension	Preservation Science, Chemistry	Conservation treatment, Scientific Observation, Analysis and Diagnosis	2017
CORE - a CRM extension aiming to address specific requirements of the conservation sector.	Extension	Preservation Science	Conservation treatment	2018
PARCOURS conservation / restoration ontology - a CIDOC-CRM extension, which focuses on conservation-restoration processes.	Extension	Preservation Science	Conservation treatment, Scientific Observation, Analysis and Diagnosis	2017
Describing Kitchener's map with a CIDOC CRM extension including major map elements	Extension	History, Geoinformatics	-	2017
Mapping MPEG-7 to CIDOC-CRM	Mapping	Library & Archival Science	Multimedia, Documentation	2011
Combining The CIDOC CRM And MPEG-7 To Describe Multimedia In Museums	Mapping	Library & Archival Science	Multimedia, Documentation	2002
Mapping VRA Core to CIDOC-CRM	Mapping	Library & Archival Science	Multimedia, Visualisation	2011
A domain ontology model for the reality-based 3D semantic annotations of the building conservation state.	Extension	Architecture, Preservation Science	Conservation treatment	2017
CulTO ontology characterizes religious historical building and supports its modeling	Extension	Architecture, Preservation Science	Documentation, Visualisation	2017
Labyrinth & Invisibilia projects - Intangible Component of Contemporary Art Ontology	Extension	CH	Visualisation	2014
Ontology for the Dutch Golden Age artworks importing Getty ULAN controlled vocabulary	Extension	History of Art	Information provenance, Scientific	2017

			observation, analysis, diagnosis	
The DOREMUS model adds new elements to FRBRoo and CIDOC-CRM whenever needed to precisely express any music-related concept or relationship	Extension	Library & Archival Science	Multimedia, Documentation	2018
OntoMP using CIDOC-CRM, FOAF and DBPedia to create virtual rooms and enable visitors to lookup individual life stories and also inter-cross information among them	Extension	Museology	Visualisation	2018
CRMpe (PARTHENOS Entities) – a super – model to support research into the human past.	Extension	CH	Information Provenance	2017

3.2 Conceptual Layering of Different Approaches

Taking into consideration the aforementioned approaches, as well as the main role of CIDOC CRM model, a conceptual correlation between different extensions and schemas is proposed. Defining CIDOC CRM as top-level ontology and center of concepts organization, we can define two more levels, one which includes the extension of entities in order to cover specialized disciplines and tasks, and one which covers related metadata schemas, respectively (Fig. 1). At the second level, the colored extensions referred to official CIDOC CRM family models. The solid lines connect extensions which have been combined in the same approach, while dashed lines present a conceptual connection between them. Finally, the colored arrows at the third level show the relevance between the different models and the corresponding domain.

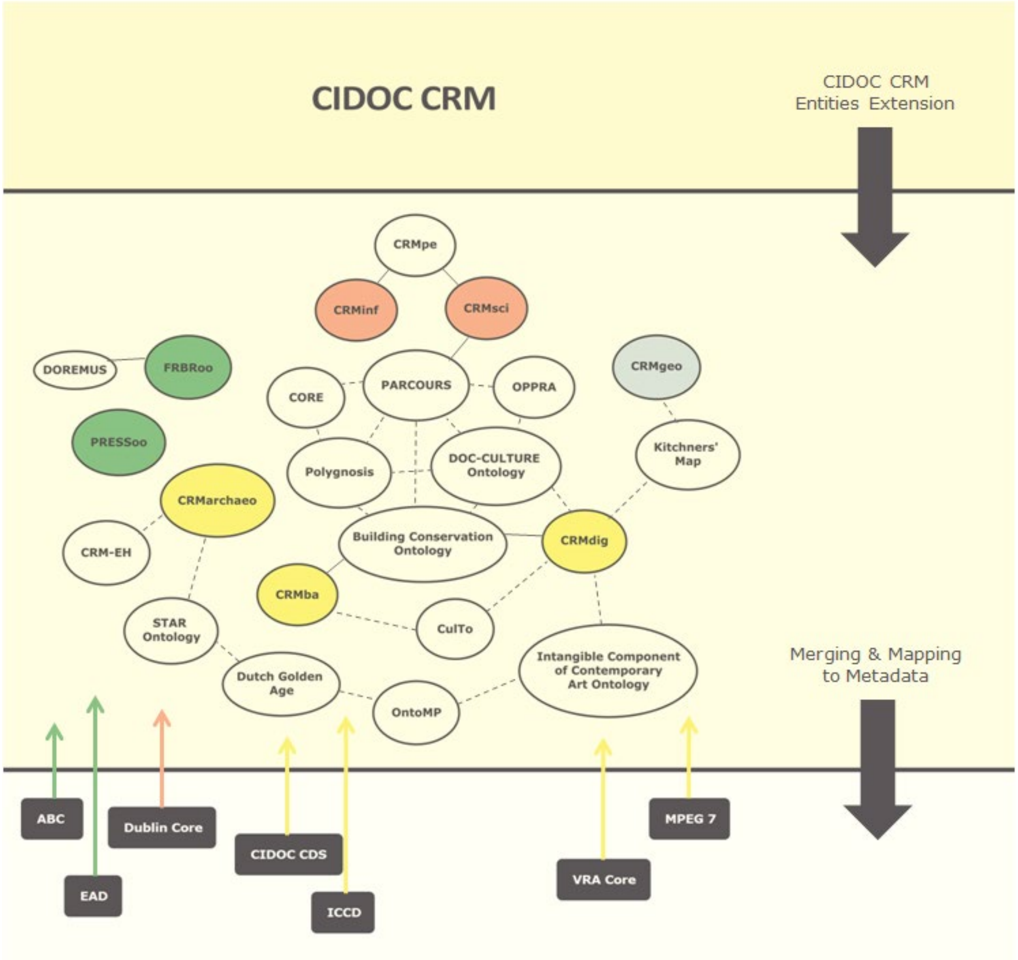

Fig. 1 Conceptual mapping and layering between different ontologies and metadata standards, posing CIDOC CRM as the base of their organization.

Our study so far, indicates a thematic connection between different approaches, since they share a common field or research goals. As we can notice on the diagram the special needs of preservation science, conservation treatment, analysis and diagnosis can be covered by a number of different extensions which focus on slightly different aspects and exploit ontologies and thesaurus. They can be also combined with compatible models such as CRMsci, CRMba, CRMdig or ontologies of other domains in order to capture the related information. For example OreChem ontology entities of chemistry domain have been included in OPPRA conservation ontology. However, it is very probable that an officially compatible model of CIDOC CRM for this sub-domain could better clarify and define some basic concepts and relations, facilitating their further specification using exclusively vocabularies and thesaurus. In the same direction, since preventive conservation activities often exploit data produced during automatic environmental monitoring by sensors or sensor networks installed in indoors (museums) and outdoors (cultural spaces, monuments) sites, it could be interesting these extensions combination with sensor data ontologies (Perlata et al 2010).

Furthermore, according to the diagram below, CRMdig is the main CIDOC-CRM extension for the digitalization, which has also been used as a basic model to further describe multimedia that enrich the documentation of cultural artifacts. As we mentioned in the previous section, there is a number of ontologies in cultural visualization field that extend the CIDOC-CRM to various domains such as 3D representation of historical buildings, 3D modeling of cultural artifacts, multimedia documentation and musical works description. However, many of these proposals were formed specifically for the intended implementation in each case, with more generic models that could be widely used still to be defined. A typical example could be the lack of ontologies that define basic concepts and relations in mobile guides and Augmented Reality museum applications, extending the CIDOC-CRM entities accordingly.

4 Conclusion and Future Work

In this work, a review of CIDOC CRM extension, mapping and merging approaches has been conducted, including both old and recent publication. According to this, a number of different disciplines and activities which are embraced in Cultural Heritage sector have defined concepts and relations based on CIDOC CRM. Also some very popular metadata schemas and standards of the CH have been matched to CIDOC CRM entities. Overall, these works verify and support CIDOC CRM role and use as a top-level ontology for the community, enrich its expressivity and preserve data interoperability.

Recapitulating, the awareness of the existing extensions and combinations of CIDOC CRM is necessary for the efficient modeling of sub-disciplines and tasks information. Proposals about entities and relations combination which may express more appropriate the knowledge and information requirements in different cases are valuable, such the ones presented on (Bruseker, Guillem and Carboni 2015). It is common knowledge that the more appropriate semantic representation of CH domain information will further facilitate its reuse and preserve its provenance, capturing a whole universe of perpetual produced data. Nevertheless, it is important to mention that the production of semantic data will expand the capabilities of new services development, related to their visualization, reasoning and interlinking.

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