HOW TO OPTIMALLY RECORD CULTURAL HERITAGE OBJECTS? DECISION SUPPORT THROUGH CONNECTED KNOWLEDGE

Stefanie Wefers[a], Ashish Karmacharya[a], Frank Boochs[a], and Guido Heinz[b]

[a] i3mainz – Institute for Spatial Information and Surveying Technology, Mainz University of Applied Sciences, Germany, {stefanie.wefers; ashish.karmacharya; frank.boochs}@hs-mainz.de; [b]Operative IT, Römisch-Germanisches Zentralmuseum – Leibniz-Forschungsinstitut für Archäologie, Germany, heinz@rgzm.de

ABSTRACT: Optical recording of material cultural heritage (CH) is a multidisciplinary activity where the understanding of cross-disciplinary semantics is vital for a successful completion. In many cases, a lack of understanding of transdisciplinary semantics slows this process down. The end users who are mostly humanities experts lack the technical knowledge of spatial and spectral recording and could therefore demand more than what is actually required or sufficient for the intended CH application. The negotiations between technical experts and the end users are a tedious process. We present a semantic-based decision support system, COSCH^{KR}, that employs reasoning and recommends optimal recording technology(ies) according to the application requirements of the recorded and processed data. COSCH^{KR} is an ontology-based knowledge model that implies the development of semantic technologies within the Semantic Web framework. It represents formalized knowledge of the disciplines involved in the process of optical recording of material CH. The paper describes the applicability of the model in spatial, spectral, and visualization applications and summarises current possibilities and challenges.

1. INTRODUCTION

Spectral and/or spatial recording and documentation of material cultural heritage (CH) is commonly used within CH disciplines to handle research questions dealing with conservation, reconstruction, understanding, interpretation etc. However, digital representations of material CH are never comprehensive but rather focus on particular information with a specific quality to fit to the requirements of the intended CH application. The decision which recording technology is capable to provide suitable data for a CH application depends on complex technical dependencies and capabilities as well as facts individual to each recording project. The decision for a technology and recording strategy is easier for all involved disciplines as soon as a common transdisciplinary understanding is achieved. As the achievement of this common understanding sometimes makes up the better part of the entire decision making, the COST Action TD1201: Colour and Space in Cultural Heritage (COSCH) started to develop a decision support system, so-called COSCH^{KR}. Being a Europe-wide platform for over 200 experts involved in CH recording, the Action was the best-suitable starting point for this development [10].

The smooth cross disciplinary communication within multi-disciplinary activities is possible when the semantics used in one disciplin is understood, accepted and applied in works conducted by the other involved disciplines and vice versa. Within IT "*semantic*" is a term used to express the need for understanding *"meaning"* of information. Henceforth, understanding semantics of other disciplines implies to making sense of information of other disciplines and apply it for the proper usage. The evolvement of the Semantic Web in late 1990s has allowed not only different disciplines but also different languages to communicate [6]. The Semantic Web applies semantic technologies that express the meaning inside the information explicitly through logical statements. This makes machines understand the meaning of information and assist human, e.g., in their action accordingly. Traditionally ontologies are used to express semantics of information [8]. These ontologies have axioms such as classes (class–subclass hierarchy), relationships between classes, and class properties. They also have theorems defining what constructs them and how. For simplicity and understandability, we call them rules. They are used inside the ontology to infer the semantics encoded inside the ontologies. An example of such a rule is *"all trains run on a track"* which infers – if an ICE is defined as train – that *"ICE is a train, it runs on a track"*.

Semantic technology has been introduced to CH domains, e.g., through CIDOC-CRM. It is a formal ontology providing foundational standards for the recording of "biographical" information about CH assets and "to facilitate the integration, mediation and interchange of heterogeneous cultural heritage information" [7]. However, so far little or no effort has been invested in the idea to use the semantics inside ontologies to infer and facilitate decision support.

2. DECISION SUPPORT SYSTEM COSCH^{KR}

COSCH Knowledge Representation or simply COSCH^{KR} is an ontology based inference model that encodes semantics of different disciplines involved in CH 3D or spectral documentation. The main intention of the model is to support end users (mostly CH experts) in the decision making process which technology(ies) optimally fit(s) to their application needs when recording a CH object in 3D or colour (including spectral bands beyond RGB).

To achieve this, the model needs to incorporate semantics of all concerned disciplines correlating with each other. For that, an agreement on co-existing semantics between different disciplines is needed which is a challenging task and can only be achieved through mutual understanding and discussion. Therefore, a series of discussions and workshops were organized to discuss and agree on the axioms and theorems (rules) that are currently included inside COSCH^{KR}.

Figure 1 represents the top-level classes and relations between the classes. Five classes constitute the top-level of the ontology:

- Physical Thing – material CH parameters such as object size, object textur etc.
- CH Applications – CH applications which make use of spectral or 3D data
- Technologies – spatial and spectral technologies and their underlying techniques and principles
- Data – data acquired by technology or required by technology or the CH Applications
- External Influences – influences from external factors such as the surrounding conditions of a material CH, the project budget etc.

The classes, their specialized hierarchy, their purposes and reasons inside the model are presented in [2].

COSCH^{KR} infers the encoded rules to support the selection of suitable technologies to record a physical CH object through a guided user input of relevant parameters. These different parameters are linked to the CH application, the characteristics of the individual CH object, and other influencing factors that may come from different external sources. Besides these individual parameters the encoded rules take limitations and challenges of technology and data into account. They are represented as respective sub-classes of the top level classes (see figure 1). In combination and as a result of the inference mechanism, COSCH^{KR} provides a suitable selection of recording technologies. The semantic definitions of axioms, the Description Logic (DL) [9] representations that define these axioms and rules are discussed in detail in [1]. The discussion in [1] is supported by an exemplary case study of "geometric alteration analysis of waterlogged wood samples" which recommends "structured light 3D scanning" as optimal 3D recording technology based on the encoded semantics of all involved components.

A huge amount of time has been invested in designing and developing COSCH^{KR}. This effort is needed due to the fact that especially such an ontology as COSCH^{KR} requires many rules and dependencies of classes and sub-classes. In addition, the involved disciplines have to achieve a mutual understanding on the general and special topics to be able to agree on the necessary cross-disciplinary semantics which are then encoded in the ontology. Our hands-on experiences are presented in [2]. Besides the above mentioned geometric alteration analysis case study, this paper discusses the effort with the example of another CH application case study which deals with the “Revelation of Underdrawings” typical for painting analyses. For this case study spectral technologies are recommended and the specific semantics are taken into account for the inference mechanism.

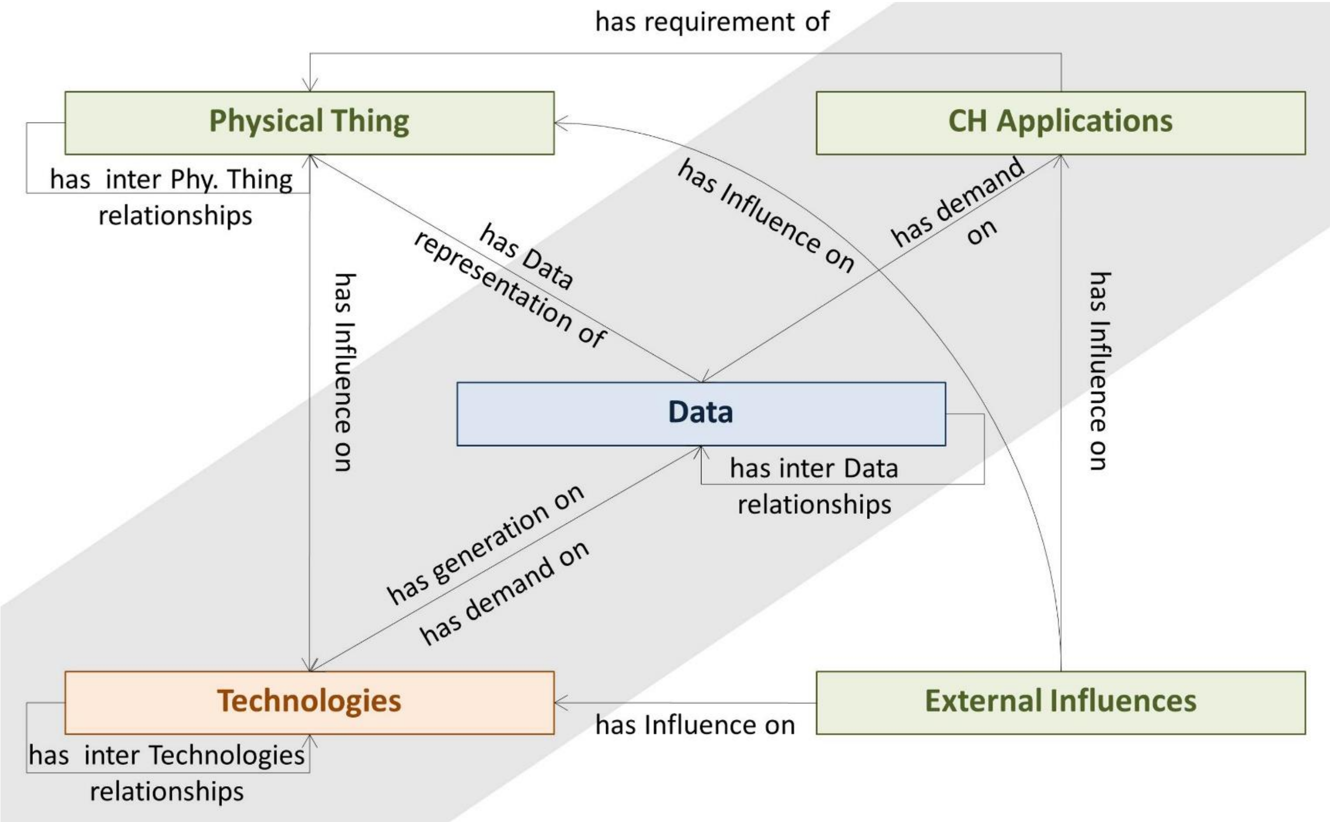

Figure 1: *Top-level classes and relations of COSCH^{KR}.*

Technologies play an important role in COSCH^{KR}. They are capable of generating data with specific characteristics (3D, colour, or other information content). However, depen-ding on the surrounding conditions, the surface characteristics of the recorded object and so on, the data generated by technologies are different. Moreover, the same technology generates different qualities of data when tested under different conditions or with different objects. In [3] we present how the same technology (laser scanning or photogrammetry) performs with different object characteristics or with different constraining conditions generating different data qualities. This demonstrates that the choice of a technology is not only application-driven but also depends on the surrounding conditions, the physical object and technical capabilities. In [4] more details are presented on the case study which was used as guideline during discussions with the experts to develop the necessary classes, dependencies and rules for the CH application “geometric alteration analysis”. The case study deals with a completed project investigating the spatial influence of various conservation treatments on ancient waterlogged wood samples. The intended interaction of the end-user with the COSCH^{KR} App system is simulated (see figure 2). It is demonstrated that only non-technical information is required from the user as input whereas all necessary technology- and data-specific information is encoded in the ontology ready for inference of a recommendation. This leads to the discussion that more CH applications (e.g., “change detection”, “mapping of ingredients in paintings”, “3D visualisation for a website”, “3D print out”) have to be implemented to provide a system convincing the CH community and other end-users. And that the entire system finally needs to be open to the community allowing further developments and enrichments but also updates.

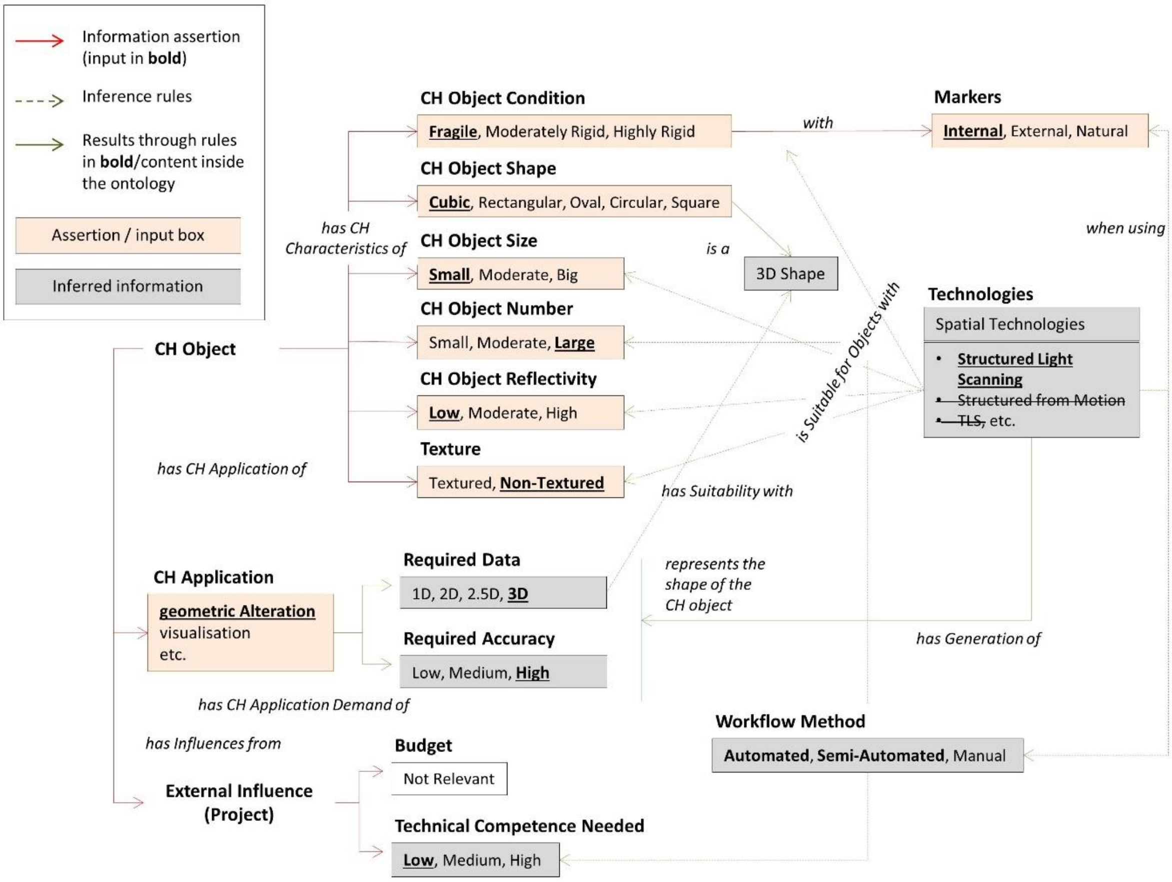

Figure 2: *GUI simulation recommending structured light scanning as recording technology for the application "geometric alteration" with individual object and surrounding parameters.*

Within [5] the scope of COSCH^{KR} is presented and it is discussed if CH applications dealing with the creation of digital 3D reconstructed models could be integrated. Such kind of visualisations commonly include interpretations of not preserved parts of a CH object. And depending on the available knowledge about the non-preserved parts including information type and content, a visualisation is more or less complex and needs more or less time and effort. A recommendation provided by COSCH^{KR} would need classes, dependencies, and rules dealing with different levels of hypotheses as well as data processing tasks and workflows. So far, COSCH^{KR}'s scope is to provide recommendations for a recording technology and not for processes and workflows.

3. OUTLOOK

Structuring and formalizing knowledge on spatial and spectral recording provides the foundation for a machine to understand the logic behind the knowledge and thus to assist human to act accordingly. This is done through reasoning the formalized knowledge. Semantic technologies use inference to infer and reason the knowledge encoded in knowledge representations such as COSCH^{KR}. Apparently, asserted knowledge represented through facts can be reasoned to discover new knowledge. In case of COSCH^{KR}, it is knowledge on optimal technology(ies) for recording a specific physical CH object with specific characteristics under certain influential characteristics and for a purpose of CH application. The idea is to include more knowledge based on expert discussion which are guided through further typical CH case studies. Currently, the inference system that will be embedded within COSCH^{KR} system and will infer the knowledge model is under development. The system will ask the end users to assert their knowledge of the application, object, surroundings and other impacting parameters. The users will be provided interactive user interfaces (as in the simulated GUI, see fig. 2). These assertions will be queried against the knowledge of the model to infer the optimal technical solution(s). The final recommendation for supporting the decision will be presented in a web-based environment and/or a document.

4. ACKNOWLEDGMENT

Part of this work was supported by the COST Action TD1201 "Colour and Space in Cultural Heritage" (www.cosch.info).

5. REFERENCES

[1] Karmacharya, A., Wefers, S., Boochs, F., Knowledge Based Recommendation on Optimal Spectral and Spatial Recording Strategy of Physical Cultural Heritage Objects. SEMAPRO 2016: The 10th International Conference on Advances in Semantic Processing, Venice, 9-13 October 2016, IARIA, 49-58.

[2] Karmacharya, A., Wefers, S.: Structuring Spectral and Spatial Recording Strategies of Cultural Heritage Assets. Background, state of affairs, and future perspectives. In: A. Bentkowska-Kafel, L. MacDonald (eds), *Digital Techniques for Documenting and Preserving Cultural Heritage*. Collection Development, Cultural Heritage and Digital Humanities. ARC Humanities Press, Leeds, 2017, pp. 157-172.

[3] Wefers, S., Karmacharya, A., Boochs, F., Ontology-based Knowledge Representation for Recommendation of Optimal Recording Strategies - Photogrammetry and Laser Scanning as Examples. *gis.Science*, vol. 3, pp. 105-113, 2017.

[4] Wefers, S., Karmacharya, A., Boochs, F., Development of a platform recommending 3D and spectral digitisation strategies. *Virtual Archaeology Review*, [S.l.], vol. 7, no. 15, pp. 18-27, 11/2016. ISSN 1989-9947.

[5] Wefers, S., Karmacharya, A., Boochs, F., Pfarr-Harfst, M.: Digital 3D reconstructed models. Using semantic technologies for recommendations in visualisation applications. *Studies in Digital Heritage*, forthcoming.

[6] Berners-Lee, T., Hendler J., Lassila. O.: The Semantic Web. *Scientific American*, pp. 34-43, May/2001.

[7] Boeuf, P. L., Doerr, M., Ore, C. E., Stead, S.: *Definition of the CIDOC Conceptual Reference Model*. ICOM/CIDOC CRM Special Interest Group, 2013.

[8] Brewster, C, O'Hara, K.: Knowledge representation with ontologies: Present challenges - Future possibilities. *International Journal of Human-Computer Studies*, pp. 563-568, 2007.

[9] Baader, F., McGuinness, D. L., Nardi, D., Schneider, P. F.: *The Description Logic Handbook: Theory, implementation and applications*. Cambridge University Press, New York, 2003.

[10] Boochs, F., Bentkowska-Kafel, A., Wefers, S.: Interdisciplinary Dialogue Towards an Enhanced Understanding of Optical Techniques for Recording Material Cultural Heritage – Results of a COST Action. In: C. E. Catalano, L. De Luca (eds), *EUROGRAPHICS Workshop on Graphics and Cultural Heritage*, Eurographics Digital Library, 2016, pp. 219-222.