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Interdisciplinary Dialogue Towards an Enhanced Understanding of Optical Techniques for Recording Material Cultural Heritage – Results of a COST Action

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Abstract

The COST Transdomain Action TD1201, Colour and Space in Cultural Heritage [COSb], 2012–2016, contributes to the conservation and preservation of cultural heritage (CH) by enhancing shared understanding, between experts from various disciplines, of the spectral and spatial recording of physical CH objects. Optimal recording, adapted to the requirements of a CH application, should involve experts from multiple disciplines and industries. Such an interdisciplinary approach is necessary "in order to protect, preserve, analyze, understand, model, virtually reproduce, document and publish important CH in Europe and beyond" [COSa]. In order to fulfil this goal, experts from 28 European countries entered into a multidisciplinary dialogue trying to establish a common understanding of spatial and spectral recording techniques best suited for particular CH applications. Several COSCH groups worked on the characterisation of spatial and spectral recording techniques; the use of algorithms and processing chains; and requirements of analysis, restoration and visualisation of CH surfaces and objects. A range of possible applications of optical techniques, now available to recording and examination of CH objects, have been tested through six COSCH case studies [BKM17]. These projects have exposed the challenges of common understanding of the processes involved, and differences in disciplinary research needs and methods. A number of issues have been identified, sometimes as basic as lack of common specialist terminology and relevant technical standards. The complexity of the field became apparent in the course of designing COSCH^{KR}, ontological knowledge representation, which employs semantic technologies. After four years of interdisciplinary dialogue, COSCH leaves a legacy that will help the dialogue to continue, technology to develop, and specialist training to better respond to the actual needs of the interdisciplinary CH research communities.

Keywords: *interdisciplinarity, material cultural heritage, recording, optical technologies, knowledge representation, COSCH*

1. Background

Recording, study and management of digital data representing material cultural heritage (CH) — to be effective — demands an interdisciplinary dialogue and collaboration. Differences between discrete disciplinary practices are understandable. The call for "bridging the gap" between disciplines involved in the study and conservation of CH has been voiced for decades [Let01].

Successful early initiatives addressing this very challenge include CAA — *Computer Applications and Quantitative Methods in Archaeology*, whose activities go back to the 1970s; the Getty Information Program and CHArt — *Computers and the History of Art*, have both been active since the 1980s. At that time analytical photogrammetry was considered cutting-edge technology, allowing for the generation of numerical results and first digital representations of objects. The use of this technique required expertise of educated technicians and specific instruments. A gap existed between technicians, as service providers, and CH experts, as end users. The end products consisted mostly of drawings and 2D maps. The dialogue between disciplines was limited and mainly concerned the agreement upon which object structures had to be extracted through an interactive compilation of stereo models.

The discovery of Roman vessels in Mainz in 1982 started an interdisciplinary dialogue around their documentation, through photogrammetry, which was carried out at the University of Applied Sciences in Mainz in close cooperation between CH experts and technicians [Rup84]. This laid the basis for a long-standing interdisciplinary collaboration on numerous projects, such as [BKM08] [Boo15], and the foundation, in 1998, of i3mainz — the Institute for Spatial Information and Surveying Technology. Technology developed, step by step, over the decades. As the potential and variety of possible products developed, so has the dialogue changed. Today, applications of some optical recording techniques, for example 3D laser scanning, structured light scanning and more recently Structure from Motion (SfM), have become common. Collaborative work on the international scale, exemplified by such ma-

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jor projects as 3D-COFORM [3D-a] and ArcLand [Arc], both scientific, and 3D-ICONS [3D-b] aimed at general audiences, led to enhanced methodologies and many exemplar applications. Considerable progress has also been made in the area of semantic representation of knowledge and metadata schema pertinent to recording material culture. The Europeana Data Model [EDM] has recognised the need to differentiate between object-related data and data related to digital representation of the object. The knowledge structured within EDM employs elements of the existing ontological vocabularies and metadata schema, including the *Art and Architecture Thesaurus* [AAT] and CIDOC-Conceptual Reference Model (CIDOC-CRM) [CID] [BDOS15]. Despite constant progress, more research is needed to integrate existing optical recording technologies, enhance their understanding and applications to documentation of CH.

2. COSCH

The COST Action TD1201, Colour and Space in Cultural Heritage [COSb], contributes to the conservation and preservation of CH by enhancing the shared understanding, between experts from various disciplines, of the spectral and spatial recording of physical CH objects. Optimal recording, adapted to the needs of a CH application, should involve experts from multiple disciplines and industries. Such an interdisciplinary approach is necessary "in order to protect, preserve, analyze, understand, model, virtually reproduce, document and publish important CH in Europe and beyond" [COSa]. In order to fulfil this goal, experts from 28 European countries entered into a multidisciplinary dialogue trying to establish a common understanding of spatial and spectral recording techniques best suited for particular CH applications. The dialogue addressed the characterisation of spatial and spectral recording techniques; the use of algorithms and processing chains; and requirements of analysis, restoration or visualization of CH surfaces and objects.

Information communication technology allows us today to put almost everything into the computer through digital representation. Material CH may also be subject of such transformations and support research into CH. However, this transition from the real to the virtual should be realised in an appropriate way. An appropriate technical solution to a specific humanities research project might not be at hand due to a huge material variety of CH, variety of research questions and varying technological capabilities. The development of a suitable technical solution strategy, adapted to the needs of CH experts, needs a careful consideration and exchange between all stakeholders. There is rarely a single solution. In an ideal scenario, a commonly accepted approach and methodology, should define the use of optical techniques in accordance with requirements defined by a particular CH application.

COSCH tries to coordinate this exchange and connects interdisciplinary specialists. When recording an actual object of CH through applications of optical technologies, its spatial properties must be considered. Material objects have a certain geometry which might be expressed by a countless number of 3D points on the surface of the object. Accordingly, technologies that provide such a type of data have to be evaluated. A second important factor is the appearance of the object. For a faithful representation this would mean providing the true (measured) colour of any part of the surface. This requires application of different techniques. Of importance is not so much a position of a surface element, but rather its spectral value. The treatment of captured data is also important. Particular attention should be paid to the choice of processing techniques. They should be adapted to the instruments used, the results required and the CH application chosen. That is why COSCH stands for appearance, **CO**lour, and geometry, **S**pace, of the **CH** object being documented through modern optical technologies. Experts from various scientific, technical and humanities fields see the COST Action as a forum that helps to identify common, or diverse, views [**?**]. This is the first step towards a common understanding that is required to, ideally, formulate the recommendations for use of modern optical technologies in a way that benefits their applications to material CH. With this objective in mind, COSCH experts in spectral and spatial technologies, and data processing, have created state-of-the-art documents, for use by CH professionals, giving an overview on selected applied techniques, including their limitations and other drawbacks.

These materials are accessible through the COSCH website [COSb]. Two-dimensional, multi- and hyperspectral imaging techniques (Vis-NIR-SWIR regions) best suited for spectral object documentation in art conservation are compiled. The identified technologies have been tested and characterised through a Round Robin Test (RRT), which was carried out in some 20 laboratories across Europe. Five test objects have been recorded by each laboratory. Various instruments were characterised according to the colour accuracy, level of illumination homogeneity, spectral accuracy and resolution, the behaviour of highly reflective surfaces, and penetration in the course of recording aiming to detect underdrawings. The results will be used to define good practices [PNV16].

Three-dimensional recording techniques, currently available, have also been identified and characterised. A variety of 3D recording techniques was applied to a fragment of a historic glazed tile and compared. Differences in the data sets were visualised [SH16].

Basic characteristics of and differences between spatial and spectral recording technologies have been highlighted, demonstrating how individual methods of data processing have a major impact on the data content and quality. COSCH experts working with algorithms provided explanations of data processing tasks such as camera colour calibration, and orthorectification, in order to draw users' attention to the role of algorithms in data treatment and processing [TM16].

Many digital technologies, including laser scanning, SfM and spectral imaging, are becoming affordable and user friendly. There is a risk they may be applied unprofessionally and without deeper understanding of the processes involved. This places a responsibility on experts and trainers to ensure access to specialist knowledge and best practice.

3. Applications of Spatial and Spectral Technologies to Cultural Heritage

By serving as a forum for highly specialised discussion of optical technologies and data processing, the above mentioned contributions are useful to lay the foundation for interdisciplinary CH discussions and projects. However, these contributions alone are still insufficient for the identified gap between engineers and CH experts to be bridged. The descriptions of technologies, as provided by COSCH, may not fully reflect the complexity of real-life examination and conservation of material CH. A CH expert may not be able to "transliterate" technical results and all the decisive parameters, capabilities, and limitations of the material CH, technology, and data application. Therefore, the following applications of spatial and spectral technologies to CH were identified through six COSCH case studies to serve as exemplars. Having evidenced possible technological support for specific areas of research into CH, they will be described in more detail [COSb], including:

- archaeological research into fragmentary objects;
- examination of historic silver coins through metrological and imaging techniques;
- examination of medieval wall paintings through digital imaging and spectral imaging techniques;
- integration and use of image data sets from various sources to support studies of historic wall paintings;
- 3D monitoring large-scale CH objects;
- adapting CH object documentation to the needs of different user groups;
- communication of CH through dynamic media content.

4. Interdisciplinary Communication

It has become apparent that a multidisciplinary vocabulary that elaborates on the nuanced understanding of concepts and individual terms is necessary. Many multidisciplinary and multilingual vocabularies do already exist, in both structured and unstructured formats. The ontological AAT [AAT] is possibly amongst most comprehensive, combining art-historical terms with scientific and technological terminology used in conservation. It represents a conceptual semantic structure of knowledge relevant to documentation of CH; includes definitions and references to literature. Although AAT is evolving, the scope of its scientific and technological terminology is at present too basic for applications of advanced optical techniques. The interdisciplinary dialogue tends to be constrained by the use of domain-specific specialist terms, which may not be understood by colleagues from another domain, and also due to the ambiguity of meaning of many terms. COSCH has prioritised the discussion of interdisciplinary terminology in a series of Think Tanks organised for the early career investigators. They represent different disciplines and different research cultures. Typically for a European network, the COSCH proceedings are conducted in English, which for most participants is a foreign language. This adds to the communication challenge and occasionally leads to misunderstandings, but also enhances one's sensitivity to an understanding other than one's own.

5. Conclusion: COSCH^{KR}

The complexity of the field became apparent in the course of designing a knowledge representation of experts involved in recording, technical examination, and digital presentation of material cultural objects through applications of optical spatial and spectral technologies. The fundamental assumption in this knowledge representation is the existence of deterministic links between (1) the requirements of a CH research question on the data content displaying the material CH which has physical characteristics and (2) the data acquisition through spatial and/or spectral recording technology, having its own intrinsic requirements and limitations [WKB].

European experts involved in the COSCH network [COSa] have the relevant interdisciplinary expertise and have been well placed to attempt the development of an ontology that reflects this specialist knowledge and structures it through classes, dependencies and rules. The aim of this knowledge representation, called COSCH^{KR}, is to recommend, based on information input by the user, how to record a historic material object, with spatial or spectral recording technology, and subsequently use the recorded digital data for a specific purpose. In contrast to CIDOC-CRM, which is "a formal ontology intended to facilitate the integration, mediation and interchange of heterogeneous cultural heritage information" [BDOS15], COSCH^{KR} does not support the management of information about material CH. COSCH^{KR} seeks to strictly represent the knowledge of the spectral and/or spatial recording. We are not aware of such an ontology being available. The new ontology should describe the parameters, rules, and limitations which play a role in the decision making about a suitable recording strategy. Based on this ontology, the COSCH^{KR} App, under development, aims to support CH experts in their exploitation of the available specialist knowledge, guiding their selection of optical technology best suited for the object and documentation needs. It is through in-depth knowledge representation, ensuring a balance between different specialist areas of knowledge, the user will be able to access suitable recommendations for his/her individual project. COSCH^{KR} will constitute a backbone of a dedicated online platform. The user will be asked to input details about the material CH under his or her investigation, in order to retrieve a recommendation for a suitable recording or examination strategy.

The ontology is expressed in Web Ontology Language (OWL). It consists of five top-level classes (Physical Thing, CH Applications, Data, External Influences, Technologies) linked through properties. This represents relevant knowledge about CH applications, technologies, data, external influences, and material CH. Size and shape, surface reflectance, etc. is, e.g., modeled within the class "PhysicalThing". Through rules and dependencies mainly the subclasses of the five top-level classes are linked [KWB16].

COSCH^{KR} App mainly aims to support non-technical CH professionals in project planning. When using the platform, specific information is automatically requested about an object to be recorded, depending on the purpose of recording. The user is becoming aware of the many important factors and parameters that must be considered beforehand. The system can also be used as educational tool for exploration of knowledge contained in the ontology.

After four years of interdisciplinary dialogue and common work we have made a significant step on a long way. How long this road is will be determined by future technological progress, its impact on the documentation of material CH and the implicated potential for such applications. It is important to start the interdisciplinary dialogue already at the very beginning of education. The gap which still has to be bridged between disciplines manifests itself early in a professional career owing to diverging education. The most effective strategy to bridge a gap is to avoid it. The benefits of interdisciplinary networks of learning [KGE*08] have been evidenced through many international initiatives. Earlier in one's career, interdisciplinary education and training offers a solution. This approach has been adopted by postgraduate courses in Heritage Science and Museum Studies, Virtual Archaeology, Digital Art History, and some modules in Digital Humanities. The inclusion of humanities subjects in science and technology courses are not common, but this situation is changing. As of 2016 the University of Applied Sciences in Mainz starts a new master's degree which combines an education in modern technology with humanities [Mas].

6. Acknowledgements

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