Part 1

COSCH CASE STUDIES

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Chapter 1

AN INTERDISCIPLINARY DISCUSSION OF THE TERMINOLOGIES USED IN CULTURAL HERITAGE RESEARCH

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ABSTRACT

Accuracy, artefact, feature, precision, reconstruction, resolution, texture, uncertainty are words central to many discussions of the documentation of cultural heritage. This terminology, whilst broadly understood across the disciplines, is often misunderstood due to its specific use in particular cases. An interdisciplinary dialogue conducted over a period of years and comprising experts in a range of fields—art history, colour science, engineering, semantics, mathematics, cultural heritage, museum studies, and others—has yielded a challenging discussion document that considers the thorny issue of a shared understanding of a set of keywords. On occasion our perceived shared language is not shared at all but reveals—at times through subtle nuance, and yet at times through gaping chasm—the disciplinary subjectivities we hold unbeknownst to ourselves. Mutual understanding of some of these key terms is central to any newly engaged, participatory transdisciplinary endeavour that seeks to develop critical methods for the documentation, analysis, preservation, and sharing of cultural heritage objects outside the traditional disciplinary silos. This chapter charts the interdisciplinary discussion towards a common understanding of terminologies used in cultural heritage. It is a discussion that recognizes critical differences or common misuse, and aims to contribute to a shared understanding that may be useful for all knowledge domains in the field. The chapter summarizes the work of a number of Think Tanks conducted by Early Career Investigators participating in the COSCH network.

Keywords: cultural heritage, interdisciplinary research terminology, metrology, humanities, digital documentation, COSCH

Introduction

The digital documentation of material cultural heritage is a multidisciplinary task and often involves experts in spectral and spatial recording, and Information and Communication Technology (ICT). When generating digital representations of objects of cultural heritage, a shared understanding is necessary to develop suitable and user-oriented solutions. However, reaching a shared understanding is complex. It begins with a clear definition of the project's aim(s), including the explanation of concepts, terms, and procedures that may be unknown to some project partners. These first steps may seem obvious and should be the basis not only for multidisciplinary projects, but for all projects. However, these tasks are more multifaceted in multidisciplinary projects as, in addition to unfamiliar disciplinary terminology, each project partner might use terms that are common to various domains, but may have inherently different meanings.

Current relevant policies of the European Union, as evidenced in many documents of the Horizon 2020 programme, require researchers: "to foster, harness and leverage collaborative interdisciplinarity . . . as a key priority for EU research and innovation policy . . . in order to come up with quicker and effective solutions to complex grand challenges and analyses of complex systems that call for crossing departmental boundaries and inter-disciplinarity to generate new knowledge of transformative power" (Allmendinger 2015, 4).

Through discussions between Early Career Investigators (ECIs) participating in the COST Action TD1201, Colour and Space in Cultural Heritage (COSCH), terms that were considered crucial for a common understanding of projects documenting material cultural heritage with spectral or spatial optical recording technologies, were identified. The ECIs were from spectral, spatial, and ICT domains, as well as from archaeology, conservation, art history, and other disciplines involved in cultural heritage research. Research into the definition of the term yields useful insight: in *Disciplinarities: Intra, Cross, Multi, Inter, Trans*, Jensenius (2012) defines interdisciplinarity as "integrating knowledge and methods from different disciplines, using a real synthesis of approaches." Using this proposition as a starting point, the COSCH Think Tanks aimed to reveal semantic discrepancies between disciplines through discussion. Benefiting from their varied backgrounds, the participating researchers worked together towards a more useful interdisciplinary approach, and indeed towards a transdisciplinarity which Jensenius (2012) defines as "creating a unity of intellectual frameworks beyond the disciplinary perspectives."

Identified Key Terms

More than 130 terms were identified as being both particular to singular domains and problematic due to their varied or ambiguous meanings across disciplines. A working document was created listing the identified terms. Each term was accompanied by a short explanation, defined as plainly as possible, and addressed to those not familiar with the respective term. A figure was added to these definitions where possible, and a reference to an explanation in the specialist literature. The list encompasses (1) spatial and spectral recording techniques, systems and devices, such as those covered in the technical section of this book, (2) terms related to methods, processes, and workflows, (3) characteristics/parameters of quality, (4) general terms used in cultural heritage domains and in cultural heritage science broadly, and (5) characteristics of surfaces of material cultural heritage.

Within this contribution we would like to focus on some of those considered most relevant by the authors.

Key Terms Which Are Domain Inherent and Might Be Unknown to Collaborating Partners from Other Disciplines

Objects of cultural heritage encompass a vast variety of materials, colours, shapes, textures, and patterns amongst other characteristics. Understanding these, their roles, and their combinations allows insight to the interrelationships between them, as well as insight into issues which may include, but are not restricted to: material provenance, manufacturing techniques, use-wear, knowledge networks, and human mobility. Conversely, this understanding may also assist in predicting and/or understanding their occurrence in new contexts, their reuse. For these reasons, the need and concern for the documentation and description of cultural heritage objects is unequivocal; that these methods are reliable, that procedures and techniques are internationally accepted is also a "given." It is the cultural heritage question one wishes to answer that determines the key properties that need to be documented and described in any given situation for a given cultural heritage object.

Consequently, proper use and reference when discussing accuracy, precision, resolution, and uncertainty, and related terms, are very important when working with any type of measurement technology—may it be a calliper or a scale, or even a 3D or hyperspectral imaging system—as inaccurate, imprecise and low-resolution measurements with a high level of uncertainty may most certainly lead to erroneous interpretations of cultural heritage objects. Following COSCH's aims, our focus here will be mainly on spatial and spectral related issues. Hence, before discussing these four selected keywords, we will first introduce some related metrological concepts and terms to enable a better understanding of the context.

Basic Metrological Concepts and Terms

Metrology is the science of measurement and its application. As such, it "includes all theoretical and practical aspects of measurement, whichever the measurement uncertainty and field of application" (ISO 2004, 13).

Once the aim of a given work or project has been set out, defining the "measurand" is the first step of any measurement procedure. According to ISO (2004) and JCGM (2012), the term measurand refers to the quantity intended to be measured—regarding material cultural heritage, this could, for instance, refer to the weight or form of an artefact, its colour, or even its chemical and elemental composition that is to be measured. Whereas the term "measurement" refers to the process of obtaining information about the magnitude of a specific quantity, where the information is the result (e.g., process: object is weighted on a scale; result: 62 g). In some cases, however, the information may consist of a set of quantity values, typically summarized as a single quantity value (i.e., an estimate, such as the average or the median of the set) and a measurement uncertainty (in this case, if considered negligible the information may be reduced to a single quantity value), see below.

Every measurement implies a measurement method and respective procedures. The "measurement method" consists of a generic description of a procedural structure used in a measurement, where the "measurement procedure," sometimes called standard operating procedure (SOP), is documented in enough detail in order to enable an operator to perform a measurement. One should not underestimate the importance of describing and documenting well the used measurement methods and procedures, as these contribute to the determination and understanding of the overall quality of the measurement results and, at the same time, to a better analysis and interpretation of the measurand—the cultural heritage object in context, in this case. Notwithstanding these issues, while "repeatability" measures the variation in measurements taken by a single instrument or operator under the same conditions (including same location, instrument, operator, procedure) and repetition over a short period of time, "reproducibility" measures the variation in measurements under a reproducibility set of conditions (e.g., different location, instrument, operator, procedure). Put simply, it measures the ability to replicate the results of others. Repeatability and reproducibility are strongly related to precision, as we will explain. By implication, one can understand the "metrological traceability chain" as a chain of alternating systems with associated procedures and standards, from a measurement result to a stated metrological reference. This, in turn, enables results to be compared because they can be traceable to the same stated reference (ISO 2004).

Of course, both measurand and the type of measurement to be performed (as well as scale of analysis, besides other issues) will most certainly dictate the type of measuring system and instrument that should be used. So, we have a "measuring system," which consists of one or more measuring instruments and other devices or substances used for making measurements (ISO 2004; JCGM 2012)—where every measurement should require as a precondition a calibrated measuring system, possibly subsequently verified (ISO 2004). And we have "measuring instruments," which can be identified or classified in distinct categories "according to unique metrological and technical characteristics that may include the measured quantity, the measuring range, and the principle or method of measurement" (OIML 2011, 19).

Accuracy

We return to the set of key terms we originally intended to discuss: accuracy, precision, resolution, and uncertainty.

The term "accuracy" is well defined in the literature (ISO 2004, 2012; Letellier et al. 2007; JCGM 2012; *English Oxford Living Dictionary* n.d.; *Merriam-Webster Dictionary* n.d.; *Encyclopaedia Britannica* n.d.) and, as such, it should not appear "abstract" for applications to cultural heritage. Accuracy refers to the degree of conformity of a measurement, calculation, or specification to the correct or truth value, or to a standard or model. Accuracy can then be determined as length measurement error of known distances in a measurement volume. In other words, the higher the accuracy, the closer the measurement result is to the true or reference object/value (JCGM 2012). Measurement conditions are also well described for a number of distinct systems and values may therefore be compared between systems. Internationally recognized standards for accuracy determination of optical 3D measurement devices have been established in VDI/VDE 2634 (2002, 2012a, 2012b) and for colour measurements in ASTM E2214 (2002, 2012). Corresponding guidelines are also well established in the industrial field. Similarly, standard procedures exist for measurement of surface roughness, waviness, and lay (i.e., rugosity and flatness) (ASME 2010; ISO 2012; Moitinho de Almeida and Rieke-Zapp 2017).

Resolution

Concerning the resolution of a measuring system, it is defined by the smallest change in the value of a measured quantity that can be meaningfully distinguished (ISO 2004; JCGM 2012).

Spatial resolution is usually understood as the smallest distance between two measured values (e.g., number of pixels per unit of length/area, number of

3D coordinates per unit of area). Nevertheless, and taking 3D spatial resolution as an example, individual 3D coordinates may represent smaller or larger areas on the object depending on the type of measuring system used. Fringe projection systems can generate one independent 3D coordinate per camera pixel, while correlation based photogrammetric techniques analyse 2D image patches for 3D coordinate calculation. The larger the correlation window is, in the latter case, the less sharp detail will show up in the resulting 3D model. Edges will appear more rounded and details lost (Kersten et al. 2016). Hence, one can understand why the number of 3D points in a model is not a good method for judging the amount of information in it (Moitinho de Almeida and Rieke-Zapp 2017). Consequently, spatial resolution should be based on the ability of, for instance, a 3D scanner to acquire separate 3D coordinates of closely-placed features (see below "feature") or a camera to produce separate image pixels of closely-placed features. Similarly, the resolution of images (AAT 1988–) and display devices (JCGM 2012), such as screens, refers to the smallest difference between its indications that can be meaningfully distinguished.

As to "spectral resolution," it can be understood as the smallest width of the electromagnetic spectrum which can be distinguished by the spectral system (the ability of a spectrometer to separate adjacent peaks in a spectrum). Spectral resolution is often combined with the description of instrument measurement range, which describes minimum and maximum wavelength detectable by it. So, for instance, an imaging system which is capable of detecting electromagnetic radiation in the range of 400–480 nm with resolution of 10 nm, shows the level of radiation in 8 partitions with each integrating radiation with wavelengths differing no more than 10 nm.

Precision

"Precision" is defined by the international standard JCGM 200:2012 (JCGM 2012) as the closeness of agreement between quantity values obtained by replicate measurements of a quantity, under specified conditions. Repeatability and reproducibility are ways of measuring precision. Precision is usually expressed numerically by measures of imprecision, such as standard deviation, variance, or coefficient of variation under the specified conditions of measurement. In short, the higher the precision, the higher the similarities between different measurements of a same object. Notwithstanding, a measuring instrument can be very precise but inaccurate, or accurate but imprecise; or very precise but have low resolution, or have high resolution but be imprecise; or any other possible combination between accuracy, precision, and resolution. Moreover, as previously mentioned, there are technical considerations, operational imperatives, and specific conditions which must be taken into account as they can interfere in the results (Moitinho de Almeida and Rieke-Zapp 2017).

Uncertainty

Measurement error is ubiquitous in scientific work. According to the International Organization for Standardization (ISO 2004, 16–17), "uncertainty" of measurement is a parameter which enables us to characterize quantitatively "the dispersion of the quantity values that are being attributed to a measurand" (i.e., the knowledge about the measurand), based on the information used. The evaluation of measurement uncertainty may be either based on the "statistical analysis of quantity values obtained by measurements under repeatability conditions" (type A); or theoretical, this is to say, by means other than statistical analysis (type B)—e.g., associated with published quantity values or with a quantity value of a certified reference material; determined by an instrument's calibration certificate (i.e., instrumental uncertainty), by the accuracy class of a verified measuring instrument, or by limits deduced through personal experience. It is worthwhile noting that the calibration of an instrument—along with the calibration of the measurements (should the instrument enable this procedure)—is an essential part of the process to ensure data integrity.

Figure 1.1. Example of sources of measurement error in 3D scanning that lead to uncertainty of measurement results (Moitinho de Almeida 2013).

Hence, when planning the measurement method it is fundamental to consider measurement error and the uncertainty of measurement results issues caused by environmental, instrumental, operator, measurand, among other factors (fig. 1.1) (Li 2011).

Terms Which Are Commonly Used That Are Ambiguous

Four terms—artefact, feature, reconstruction, and texture—are presented briefly on the one hand from a cultural heritage perspective and on the other hand from a technical perspective, illustrating the dimensions for a potential misunderstanding within interdisciplinary discussion and projects.

Artefact

Focusing on the spatial and/or spectral recording of cultural heritage objects, the first term to be explained is "artefact" which has to be seen in context of the term "cultural object." The latter is defined as an object significant to the archaeology, history, architecture, science, or technology of a specific culture (UNESCO 2003a, 2016a). Cultural objects may be classified as intangible (e.g., traditions, social practices, performing arts, knowledge, and skills) or tangible, and in this case as immovable or movable. Examples of cultural immovable objects are built and natural monuments, movable objects are ecofacts and artefacts (UNESCO 2016a, 2016b). Ecofacts constitute a large class of natural materials that have relevance to human action and behaviour in the past—e.g., pollen, plant remains, charcoal, animal bone, coprolites, residues. Whereas the term "archaeological artefact" refers to any portable object manufactured, modified, or used by humans (AIA n.d.)—e.g., lithics, sculptures, potsherds, or coins.

The context in which an archaeological artefact is found is of special interest for its analysis and interpretation, as it may enable a more precise dating and give evidence for social actions (e.g., manufacture, usage, discarding). Furthermore, the information about its find spot may enable the researcher to put it into a broader context, for example, by mapping similarities, dependencies, and connections to other contexts, artefacts, and evidences, towards a better understanding of past societies. As a rule, one may say that the more information about an artefact and its context is available the more valuable it is for archaeological research (Jones 2003; Eggert 2013). However, more than data quantity it is data quality and adequacy that is needed (Moitinho de Almeida 2013).

For museum objects, the Getty *Art & Architecture Thesaurus* (AAT 1988–) uses "cultural artefact." In the cultural heritage field, a "digital artefact" is usually understood as a digital surrogate/representation of a cultural heritage or archaeological artefact—an example of this could be a 3D digital model of a Roman amphora.

When referring to computers, electronics, and optics, "artefacts," more commonly known as "digital artefacts," "computational artefacts," or "noise" (although these terms may as well convey other meanings) are unintended and unwanted errors, distortions or other aberrations that occur due to transmission errors or signal processing operations (Horak 2008)—that is, during the acquisition, transmission, processing, conversion, or compression of analogue or digital signals or data—which are typically caused by a limitation or malfunction in the measuring system or software. Artefacts are not always easily detectable, but can sometimes be encountered in digital images, 3D scanned models, or spectral data, amongst other research areas.

Feature

The term “feature” is often used in archaeology with two distinct meanings, either referring to “a set of contexts” (Carver 2005, 82) in which archaeological evidence is discovered, or to the distinctive parts, characteristics, or attributes of archaeological evidence. Notwithstanding this, both meanings of “feature” are likely to give insight into former human actions. An example of feature as “a set of contexts” could be a number of holes dug in the past to hold posts for constructing a pile-dwelling (or stilt house) and refilled later on due to the destruction of the house. These two events (i.e., construction and destruction) could be interpreted in the present, after the detection and analysis of discolouration patterns of the soil. However, such features, or individual contexts, may contain one or more artefacts, ecofacts, or any other type of archaeological evidences, where each one has in turn its own features (here meaning distinctive parts, characteristics, or attributes)—for instance, an artefact with a specific colour, shape, texture, pattern, material, etc. (Eggert 2013; see various chapters in Renfrew and Bahn 2005).

In computer vision, the term “feature” coincides to a certain extent with the second meaning aforementioned—i.e., “distinctive parts, characteristics or attributes”—as it is understood as an element (or part of data) in image or 3D data which ideally can be automatically distinguished and described using processing algorithms. Such elements can be used for image (or 3D data) matching and stitching using corresponding points, pattern recognition and object classification. Features can be extracted by means of intensity, hue, curvature, and other parameter analyses (Roth 1999; Lowe 2004; Mikolajczyk and Tuytelaars 2009; Hołowko et al. 2014; for typical computer vision applications see: Hassaballah et al. 2016).

Reconstruction

For much of the literature found in the cultural heritage field (The Heritage Canada Foundation 1983; Seville Principles 2011; AAT 1988–), “reconstruction” involves the construction of a new object, building, or structure, that represents, as closely as possible, a cultural heritage object that has been entirely or partially lost. These references seem to be very limited. They only consider a number of physical and visual reconstructions, apparently ignoring all non-visual and immaterial cultural heritage. In any case, reconstructions, such as computer models, or works in other media, which enable a proposed representation of how some thing or place may have been or looked, an activity had been done, an implement was used, or some actor may have behaved at a previous time, are carried out on the basis of archaeological, historic, literary, graphic, and pictorial, or other similar evidence. Reconstructions raise concerns in many instances about accuracy and uncertainty, especially when certain features are based on conjecture instead of clear evidence. To follow AAT (IDs: 300387703 and 300389893), "digital reconstruction"—also referred to as "virtual reconstruction"—is a specific branch of reconstruction, in the sense that it makes use of computers and appropriate programming language or software to construct digitally, or "fill in the losses and lacunae" of missing digital data, including those of digital representations of cultural heritage objects. Physical (i.e., real world) and digital reconstructions (e.g., experimental archaeology and computer simulation methods and techniques) have already demonstrated their usefulness in helping to gain practical knowledge and in testing theoretical hypotheses (Ingersoll et al. 1977; Skibo 1992; Terradas and Clemente 2001; Hopkins 2008; Moitinho de Almeida 2013; Moitinho de Almeida et al. 2013; Pfarr-Harfst and Wefers 2016).

Texture

Texture is usually defined as those attributes of an object's surface having either visual or tactile variety, and defining the appearance of the surface (Tuceryan and Jain 1998; Fleming 1999; Mirmehdi et al. 2008; Engler and Randle 2009; AAT 1988–). Hence, it is useful to distinguish visual appearance (e.g., colour variations, brightness, reflectivity, and transparency) from tactile appearance (e.g., microtopography, soil texture).

Visual appearance is perceived as complex patterns composed of spatially organized, repeated subpatterns, which have a characteristic, somewhat uniform appearance, under certain viewing and measurement conditions (Leung and Malik 2001; Szczypinski et al. 2009). For instance, an inlaid marble floor from a Renaissance house is differently perceived by a human observer depending on the viewing direction, light source, and a range of other variables. In digital/electronic imaging, an "image texture" can be understood as a two-dimensional image representation of the surface texture under certain conditions—and we have already explained that different conditions may likely yield different results, in this case, of textures. While "texture mapping" consists in applying a two-dimensional image file containing texture, colour (this can also be applied as "colour per vertex"), or surface detail to a 3D model or computer-generated graphic (AAT 1988–)—other types of mapping include height, bump, normal, displacement, reflection, specular, and occlusion.

The real surface of an object can be defined as a set of features which physically exist and separate the entire workpiece from the surrounding medium (ISO 1996), where the texture of the surface—here, its topography, as a scale-limited complex combination of spatial frequencies—is just one of its key features. In simple terms, tactile variation can be understood as the geometrical irregularities that emerge when considering roughness, waviness, and lay—a "3D texture." ASME (2010) (fig. 1.2) defines roughness as the finer spaced irregularities of the

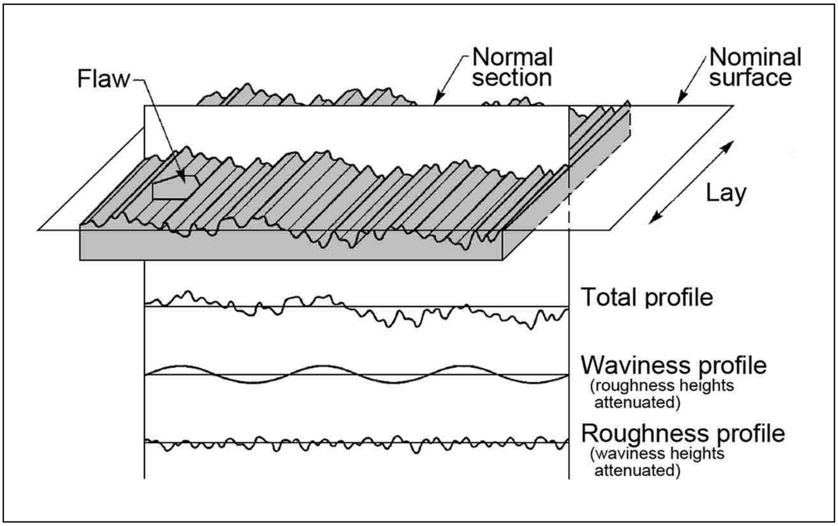

Figure 1.2. Schematic diagram of surface characteristics. Adapted and reprinted from ASME B46.1-2009, by permission of the American Society of Mechanical Engineers. All rights reserved.

surface texture that usually result from the inherent action of the production or material conditions; waviness, as the more widely spaced component of the surface texture, where roughness may be considered as superimposed on a wavy surface; and finally lay, as the predominant direction of the surface pattern, ordinarily determined by the production method used. As to "soil texture," it refers to the percentage of different sizes of particles smaller than 2 mm in a volume of soil (SCS-USDA 1993), not necessarily taken from the surface of the ground.

In general, texture can be characterized either from physical or digital data, from macroscale to nanoscale, using advanced metrology methods and techniques, and by means of 2D or 3D imaging contact or non-contact instruments, which span a wide range and resolution (Moitinho de Almeida 2013).

Example Scenario

As an example, we would like to implement the terms explained above on the basis of the aims and outcomes of an interdisciplinary three-year project (2010–12) "Der byzantinische Mühlen- und Werkstattkomplex in Hanghaus 2 von Ephesos (TR)" (The Byzantine milling and workshop complex in Terrace House 2 of Ephesos, Turkey) (www.rgzm.de/ephesos).

The aim of the project was to investigate the Late-Antique/early Byzantine (late third century to early seventh century AD) water-powered workshops in Terrace House 2 of Ephesos, Turkey, focusing on its construction including the type, number and capacity of workshops and machines powered by varieties of waterwheels, their duration of use and reasons for their abandonment including the investigation of artefacts for absolute dating and in order to understand the economic impact of the workshops through provenance analyses of raw materials (Mangartz and Wefers 2010; Wefers 2015, 2016).

This entire feature is located on a slope with an altitude difference of ca. 30 m. It was completely covered with earth until it was excavated in several archaeological excavations carried out in the 1960s, ’70s and ’80s. It is constructed of stonewalls up to a height of 5 m and preserved in relatively good condition. Several archaeological artefacts, such as coins, potsherds, millstone fragments, among many other types of evidence, have been found and are now stored in archaeological depots. Since 2000, Terrace House 2 is covered by a modern protective roof and is part of the antique site at Ephesos which is open to the public.

The measurand consisted of the entire feature, ca. 100 m × 30 m. The measurement method applied during the 2010 and 2011 archaeological surveys was established according to the aims of the project, expenditure of time on site, logistics, and finally the budget. The measuring system included a combination of three distinct measuring instruments—a tachymeter, a digital single-lens reflex camera (DSLR), and a phase-based laser scanner—where each one has its own specificities and therefore measurement procedures (only a brief overview of methods and procedures used is given here. For a detailed description see Cramer and Heinz 2015; Wefers and Cramer 2014). A tachymeter with an accuracy of 2–3 cm was used to set up a reference system based on the local Ephesos reference system, to enable an adequate alignment of the measurements acquired by the laser scanner. The measurement procedure consisted of setting up well distributed reference points—at least three reference points and targets had to be visible from each scanning position. A DSLR camera (Fuji FinePix S3Pro, Nikon Fisheye 10.5 mm, 4256 × 2448 pixel, 3 times exposure for each view) was used to capture image texture—to be later texture-mapped onto the 3D model—and to generate LDR-360°-panoramic views (12000 × 6000 pixel) for visualization and dissemination purposes.

The phase-based laser scanner (Leica HDS6000) was used to acquire the 3D digital measurements (the 3D coordinates). This instrument’s specifications on accuracy, resolution, precision, and uncertainty of measurement are made available by the manufacturer in the corresponding manual (Leica HDS6000). The measurement procedure was the following: ca. 100 scanner positions were necessary to record the complex overall geometry of the feature. The 3D point cloud resolution was reduced to a minimal point distance of 1 cm, which was sufficient for such a large feature with respect to the project's aims, as well as to the overall data volume and handling. A higher resolution would be required to analyse specific features, such as the roughness—the topography of texture, made up of fine details of the surface of the millstones. Additionally, unnecessary areas, such as the points representing the modern protection roof and computational artefacts, were removed. The individual point clouds were aligned, making use of the reference system produced by the tachymeter. The result of the measurements after post-processing was a point cloud of ca. 500 million points.

The scanner and camera were used one after the other at a fixed position in order to enable combining both 3D data and colour data into one single digital model based on the local Ephesos reference system—an important aspect as further investigations would be conducted outside Ephesos, in Germany. The 3D data set was saved as a document for archiving purposes at the Austrian Archaeological Institute, which is the key stakeholder of the site in Turkey.

However, had the objective been to acquire 3D digital measurements of the aforementioned excavated artefacts for research purposes, the selected 3D measuring instrument would have eventually been different. Taking a coin as an exemplar artefact, which are typically small in size and have fine details, to use a measuring instrument with a resolution of 1 cm would have definitely been inadequate as the smallest geometrical feature expected to be identified should not be smaller than 2 cm, meaning in many cases the whole coin or most of it. More adequate measuring instruments could eventually include 3D close-range structured-light scanner, laser scanner, macro-photogrammetry, digital microscopy, amongst others. Additionally, a good 3D measuring instrument for a coin will be both precise and accurate by acquiring the same 3D coordinates of the coin each time (repeatability, e.g., measurement results: diameter of coin is either 2.819 cm or 2.82 cm each time) and each time they are close to the real coin (e.g., diameter of real coin is 2.8 cm)—within this type of study, the measurement uncertainty may be negligible. All in all, depending on the scientific question prompting the research agenda and the scale of analysis required, among other factors, the accuracy, resolution, precision, and uncertainties of the measurements should be high enough to fulfil the project's or expert's needs for improved scientific documentation and study of the cultural heritage object (Moitinho de Almeida 2013).

A digital model of the workshop complex was reconstructed on the basis of the measurements of the feature and artefacts, as well as archaeological conclusions drawn from comparative studies and logical correlation (Koob et al. 2011). Furthermore, a physical 1:1 scale model of the stone sawing machine was reconstructed for experimental reasons. Experiments with various setups were performed to test hypotheses within the up-to-that-point only theoretical reconstruction of the stone sawing machine. These experiments finally gave evidence for one of the various setups and helped clarify the overall operating mode of the machine, the workshop, and the individuals at the site (Mangartz and Wefers 2010; Wefers 2015).

Conclusion

As a European research forum the COSCH Action aimed to foster a better understanding of the digital recording of material cultural heritage, to define good practice and stimulate research in this area (COSCH MoU 2012). A key challenge in this context was the language which is rich in vocabulary. Words have different meanings, depending on how and where they are used. As in everyday life we have to explain or contextualize certain terms in order to ensure the same understanding and not simply the primarily comprehensible issues when using a foreign language, but particularly for domain knowledge. This is very often the case for international projects where experts might choose English, particularly in a European research context. In a European Research Area (ERA) environment where researchers are encouraged to engage in inter- and transdisciplinary work this linguistic challenge is increased due to terms such as those explained in this chapter.

Further to that and vital to COSCH, the work presented here, which is only a small part of the ECI's work, can be understood as a semantic contribution to the development of controlled vocabularies—to eliminate as much as possible these variations in understanding and interpretation, in order to create machine readable and properly semantically enabled work. The aim of this is to harness the combined intelligence of ECIs across the EU in a variety of domains to eliminate this variability and thus to create better science. This is not the same as saying words have different meanings depending on when and where they are used. Instead, the aim is to define those meanings in a way that is intelligible to other scientists, and machine readable in the semantic sense. The Web Ontology Language (OWL) and Resource Description Framework in Attributes (RDFa) both rely on the work of human beings to generate the controlled vocabularies necessary for machine reading—it is only through working together that a true transdisciplinary understanding may emerge. Unlike collaboration or simple cross-disciplinarity, this work aims to be profoundly interdisciplinary—where the participants, working together, put themselves in the disciplinary contexts of the other, rather than a basic collaboration which would not yield as transformative a result. It is only through interdisciplinary work "integrating knowledge and methods from different disciplines, using a real synthesis of approaches" (Jensenius 2012) that the stated ERA goals may be achieved: "To explore and exploit new types of problem-driven and user-oriented research programs that go way beyond well-established modes . . . . To stimulate disruptive innovations to accelerate value creation" (Allmendinger 2015, 4) in the cultural heritage domain and beyond.