Toward cultural significance awareness in HIS: a data model approach

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Abstract
Purpose – The purpose of this paper is to address the challenging issue of developing a quantitative approach for the representation of cultural significance data in Heritage Information Systems. We propose to provide experts in the field with a dedicated framework to structure and integrate targeted data about historical objects' significance in such environments.
Design/methodology/approach – This research seeks the identification of key indicators which allow to better inform decision-makers about cultural significance. Identified concepts are formalized in a data structure through Conceptual Data Modelling, taking advantage on Unified Modeling Language. The Design Science Research method is implemented to facilitate the development of the data model.
Findings – This paper proposes a practical solution for the formalization of data related to the significance of objects in Heritage Information Systems. We end up with a data model which enables multiple knowledge representations through data analysis and information retrieval.
Originality/value – The framework proposed in this article supports a more sustainable vision of heritage preservation as it enhances the involvement of all stakeholders in the conservation and management of historical sites. The data model supports explicit communications of the significance of historical objects and strengthens the synergy between the stakeholders involved in different phases of the conservation process.
Keywords – Cultural Heritage, Cultural Significance, Heritage Information System, Values, Degree of Significance, Data model
Paper type – Research paper

1. Introduction

The increasingly complex management of heritage information led researchers to focus on the development of a common framework to centralize all data in a single environment (Poux *et al.*, 2020). Besides enhancing data accessibility and transmission, such information systems (IS) enable the identification and analysis of relationships among multifaceted data. Heritage Information Systems (HIS) allow the representation and management of information related to the spatial, temporal (Hallot and Billen, 2018) and multiple thematic dimensions related to heritage places (López *et al.*, 2020).

Conservation aims at retaining the cultural significance of places (Australia ICOMOS, 2013). Assessing significance is critical since "*values strongly shape the decisions that are made*"(Mason, 2002). Therefore, such knowledge should be integrated in HIS to allow providing explicit representations of cultural significance data (Clark, 2019) and enhance its operational dimension in conservation projects. Nevertheless, several issues challenge the operation. First, assessments of significance are intended to inform policies and planning decisions "while being relevant to all the disciplines and stakeholders involved" (Mason, 2002). Regardless of their expertise, knowledge, and degree of involvement, providing all stakeholders with the same level of information about cultural significance is critical to ensure the sensibility of conservation actions regarding this aspect. Then, due to the subjective dimension of values (Kapelouzou, 2012), any attempt to reduce assessments and representations of objects' significance to a mathematic formula is doomed to failure (Brandi, 1963). Although (Fredheim and Khalaf, 2016) indicate that "quantitative assessments of significance are problematic", they also recall that "qualitative or semi-quantitative assessments are necessary". Considering the myriad ways in which heritage is perceived and valued, "a more effective way of treating this issue has to begin with a clear, effectively neutral, agreed-upon way of characterizing different types of heritage value" (Mason, 2002). (Fredheim and Khalaf, 2016) proposed a dedicated framework intended to be more flexible and inclusive than previously established values typologies and (Jouan and Hallot, 2020) suggested to take advantage on this process to structure cultural significance data in HIS.

In this paper, we address the issue of formalizing significance assessments to enable explicit communications about detected values, make such knowledge more accessible for non-expert stakeholders, improve the synergy between experts along the conservation cycle and feed new interpretations about the significance of historical sites. We postulate that enhancing such interactions enables a more operational use of cultural significance information and allows avoiding misunderstandings about the objectives of conservation. This article investigates the possibility to elaborate a dedicated data model with a particular focus on the representation of objects' Degree of Significance (DoS) in HIS. The elaboration of a method for capturing the interpretations of all social groups involved in a conservation project is out of the defined scope and will be dealt with in future works so it can benefit from the outcomes highlighted in this publication.

Key concepts implemented to qualify the DoS of historical objects can be extracted from scientific literature in the field of Cultural Heritage (CH). As the implementation of these ideas at a conceptual level obstructs the inclusion of non-expert stakeholders, we seek the identification of underlying notions, indicators of heritage places' DoS, and further integrate them in the model. Providing with simplified representations of a phenomenon of interest, indicators inform decision-makers who further compare, interpret and balance their importance according to their own sensitivity but also considering other aspects like the priorities and values defended by their organizations. The use of indicators to inform decisions is common practice in other fields of study (Dempsey *et al.*, 2005; Ferraz *et al.*, 2020). In the field of medicine, while targeted indicators inform decisions about the potential risks and benefits of different treatments and remedies, the choice directly depends on "the values, or utilities, that patients place on different health states and health outcomes" (Reyna *et al.*, 2009).

After this introduction, we depict a state of the art. The methodology implemented is presented in the third chapter together with some guidelines orienting the design of the data model. The elaborated data model is then presented in section 4. Modelling issues and further research perspectives are then addressed.

2. State of the art

Heritage information is multimodal, multiform, strongly related to the spatial and temporal dimensions of heritage assets and often associated with a certain degree of subjectivity and uncertainty (De Runz and Desjardin, 2010; Van Ruymbeke *et al.*, 2015). Managing such heterogeneous data requires adopting tailored HIS to facilitate the collaboration amongst experts, enable the diffusion of generated knowledge and ensure its transmission to future generations. HIS integrate both spatial data related to the tangible dimension of historical places and semantic layers dealing with different aspects of their history. 3D reconstruction of multiple states of existence of historical places allow to document their spatiotemporal evolution (Rodríguez-Gonzálvez *et al.*, 2018). Though (Saygi and Remondino, 2013) highlight that "for a deep and holistic understanding of multi-layered spatial information, the use of semantically enriched 3D models stands as the best solution", they recall that there is no off-the-shelves solution. Facilitating data retrieval in spatial databases, the use of Geographic Information Systems (GIS) in such context is widespread (Meyer *et al.*, 2007). Nevertheless, the rather territorial dimension of GIS and their limitations in the management of 3D data challenge their application at smaller scales. Considering its crucial spatial dependence, alternative approaches allow to associate cultural heritage information on heritage objects' 3d models by mapping thematic layers on their surfaces (López *et al.*, 2020; Soler *et al.*, 2013).

The technological progress in 3D modelling solutions and the data standards developed in the construction sector led experts to consider other solutions. Building Information Modelling is now regarded as a pertinent alternative for the digital documentation of historical places (Pocobelli *et al.*, 2018). Recent progress allowed to extend BIM software's capacity to meet experts' requirements in terms of knowledge representation. Nevertheless, the Industry Foundation Classes (IFC), BIM' standard for interoperability, is not adapted to deal with the temporal dimension and uncertainty characterizing heritage information. Concerning the latter, as "recreating a lost building or building phase invariably means making hypotheses and suppositions" (Boeykens *et al.*, 2018), multiple methods have been proposed for historical validation of the geometric models (Bianchini and Nicastro, 2018; Boeykens *et al.*, 2018). Regarding the former, although execution phases in BIM software might be used to document different states of existence in BIM environment (León-Robles *et al.*, 2019), the representation of different sequences considering various hypothesis related to different sources of information is not possible. Finally, considering IFC limitations in terms of knowledge management, several authors suggested to adopt an hybrid approach taking advantage on BIM & CAD software to represent the spatiality of assets and on semantic technologies to model non-geometric data (Acierno *et al.*, 2017; Quattrini *et al.*, 2017).

Current practices in the field of heritage conservation recognize the significance of historical places in the multiplicity of values (Araoz, 2011) associated by a wide variety of stakeholders and therefore no longer limited to the sole perspective of experts. The values turn discussed in (Avrami and Mason, 2019) led to consider values as fluctuating judgements depending on the observed object, on the observing subject and on the context of their interaction (Mendes Zancheti and Ferreira Hidaka, 2020). Values are not necessarily positive, "not intrinsic; mutable, not static; multiple and often incommensurable or in conflict" (de la Torre, 2013). Along with the adoption of value-based strategies for the conservation and management of the built heritage, several values typologies have been proposed to make value assessments more explicit and accessible to the variety of stakeholders involved, such as the Nara grid (Van Balen, 2008). Arguing that most typologies "often fail to prompt the necessary questions to develop satisfactorily detailed understandings of heritage significance", (Fredheim and Khalaf, 2016) propose a 3 steps framework that enhances the integration of non-expert and non-informed stakeholders in the process. These developments allow to consider new avenues to move towards a quantitative representation of cultural significance data in HIS. Although there exist a wide variety of systems supporting evaluations of objects' significance, we adopt the Model of Fredheim & Khalaf (FKM) for the reasons discussed above. Following paragraphs further explain the three stages of the process (Figure 1).

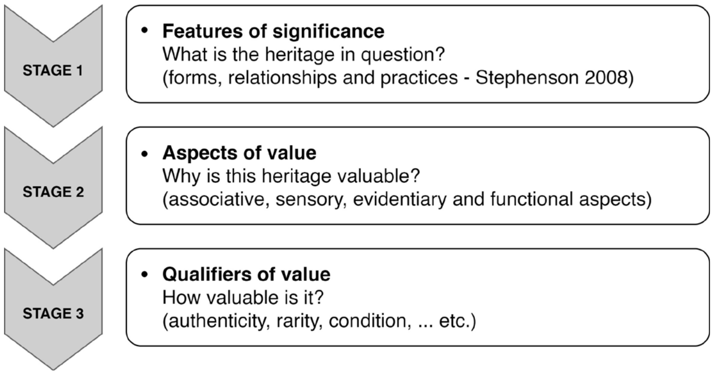

Figure 1 - FKM for the assessment of heritage assets' significance.

The first phase implies the identification of features of significance. Fredheim & Khalaf seem to have overcome some limitations pointed out by Heras (Heras *et al.*, 2013) concerning intangible features and the multiples scales to be considered. First, they integrate the three categories of heritage objects of the Cultural Values Model (Stephenson, 2008) embodying both tangible (forms) and intangible (relationships and practices) features. Features of significance are both considered as individual heritage objects and as heritage sites potentially containing a set of other objects that can be identified according to the needs and objectives of the project. Features are related, in a second step, with the different values they convey. These value judgements are sorted in four categories corresponding to different aspects of value: Associative, sensory, evidentiary and functional. The interest of this system, already implemented in (Houbart and Hallot, 2021), lies in the fact that it is short and inclusive while "being very comprehensive". Although specific values can be carried by multiple objects, we do not conserve them all, we operate a selection based on value judgements. The explicit identification and communication of their DoS is crucial to assist stakeholders in defining appropriate protection and conservation measures and in prioritizing interventions.

The last step of the value assessment process aims at determining objects' DoS. Regarding the criteria used to evaluate object's DoS, this research focuses on the concepts of rarity, authenticity, and integrity although other qualifiers might come into play. First, as rarity qualifies a relationship between an object to others of the same kind, quantitative representations of some aspects of objects' rarity are possible. Secondly, authenticity and integrity have progressively been implemented to evaluate the suitability of nominated properties to the World Heritage List (Jokilehto, 2011). Despite the theoretical advances made in Nara (Cameron, 2019), Stovel highlighted the persisting confusion in the application of authenticity and integrity as qualifying conditions, which limits their practical utility in shaping management and conservation strategies (Stovel, 2007). Instead of dropping the concepts, many authors proposed to analyze and deconstruct the two concepts to propose a more pragmatic approach (Houbart and Dawans, 2011; Jokilehto, 2009; Lowenthal, 1994; Stovel, 2007). Among the different prisms considered by these authors, we identify four underlying concepts that allow generating more explicit representation of historical objects' DoS in HIS. We distinguish the spatial-temporal evolution of objects (1), their condition and vulnerability (2), the uncertainty of information sources (3) as well as the aspects of their integrity (4) impacting their ability to convey associated values.

3. Methodology

3.1. Research method

To address highlighted issues, it has been suggested to provide experts in the field with a dedicated framework to structure and integrate such data in HIS. This research uses the data model developed in (Jouan and Hallot, 2020) as a guideline and aims at further addressing some practical issues to clarify implications in terms of data encoding and information retrieval in HIS. Widespread in the field of IS, Design Science Research (DSR) is implemented as it allows approaching "a design problem at an abstract and generalizable level, relying heavily on deductive reasoning"(Conboy *et al.*, 2015). Its iterative dimension enables the development and progressive refinement of a prototype. DSR process (Figure 2) (Lawrence *et al.*, 2010) consists of several steps; problem statement, definition of the solution's objectives, elaboration of the artefact, implementation, evaluation of its efficiency and finally the diffusion of the product.

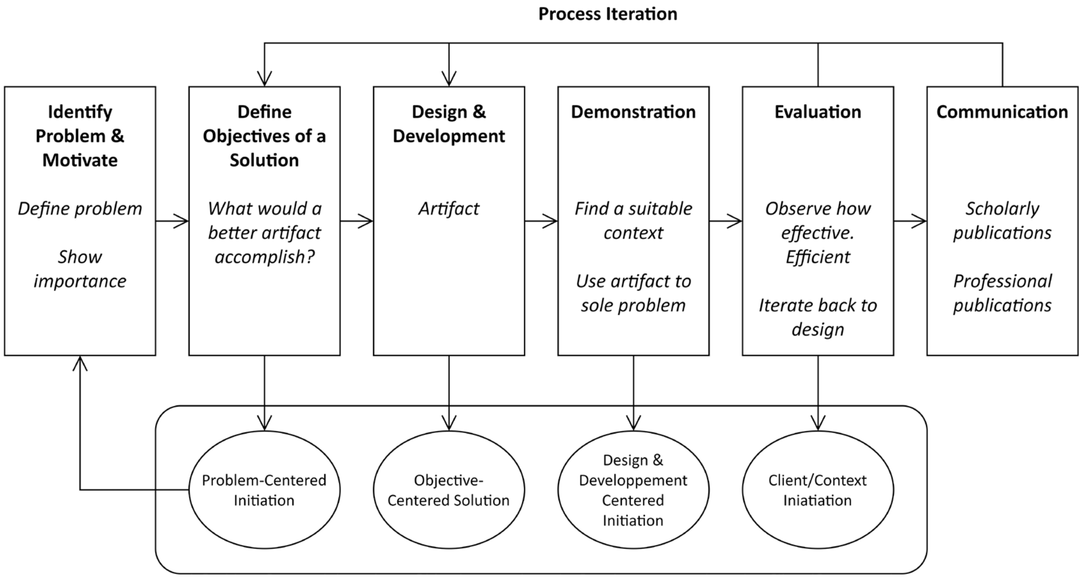

Figure 2 - This scheme depicts the main steps of the DSR process, according to (Lawrence *et al.*, 2010).

3.2. Design principles for the Data Model

Based on an analysis of existing formalisms, two principles were identified to guide the design of our data model.

- *Design principle 1: The data model should integrate pertinent data specifications according to the objectives of the work.*

Organizations in the CH sector usually adopt specific HIS with a data structure tailored to their needs integrating national and international data specifications to ensure the long-term preservation and usability of the information and to facilitate data sharing and accessibility (Richards *et al.*, 2013). Dedicated formal ontologies have been elaborated to address data heterogeneity issues and to support semantic interoperability in data exchange amongst organizations (Lodi et al., 2017). The Conceptual Reference Model (CRM) of the international committee for documentation (CIDOC) is the most widespread formalism for heritage information, among others like the European Data Model (EDM) (Ranjgar *et al.*, 2019). Besides the core model, several extensions extend the scope of the ontology to specific domains. In this case, it appears particularly important to integrate the CIDOC CRM and compatible models, as well as to connect the model to the IFC standard. Mapping our data model in these formalisms require identifying correspondences between concepts mapped in the latter and in the developed model (Van Ruymbeke *et al.*, 2017). At this stage, indications can be given about key concepts that potentially enable achieving these connections.

- *Design principle 2: The data model should integrate, improve, or extend existing data structures considered pertinent regarding the objectives of the research.*

There already exist many data models to support the structuration of heritage information. For instance, ontological frameworks have been developed to support the documentation of objects' condition (Cacciotti et al., 2015; Messaoudi et al., 2018), to facilitate heritage information management along the conservation process (Acierno et al., 2017) or to represent the spatiotemporal evolution of historical sites (De Luca, 2011).

3.3. Extending the Multiple Interpretation Data Model

As products of human activities, features of significance are called upon to change, we briefly address the question of objects' identity to avoid compromising the data model' stability. Considering that "the identity of an object is defined as the unique characteristic which distinguishes it from all other objects" (Hallot and Billen, 2016), any change to an object would lead to consider the new version of itself as a distinct object, as illustrates the thought experiment of Theseus' ship. Nevertheless, the operational perspective of this article imposes a certain abstraction to ensure the continuity of object's identity despite the numerous changes and modifications occurring along their lifecycle. We propose to adopt the vision proposed by (Van Ruymbeke *et al.*, 2015) for the development of the Multiple Interpretation Data Model (MIDM) (Figure 3) to ensure the necessary flexibility and stability of the model. The MIDM enables documenting the spatial-temporal evolution of historical objects to support the elaboration of an Archaeological Information System. Although temporality, spatiality and functionality are considered as essential components of objects' identity, the MIDM allows to consider the temporal continuity of objects regardless of possible discontinuities of the spatial and functional dimension.

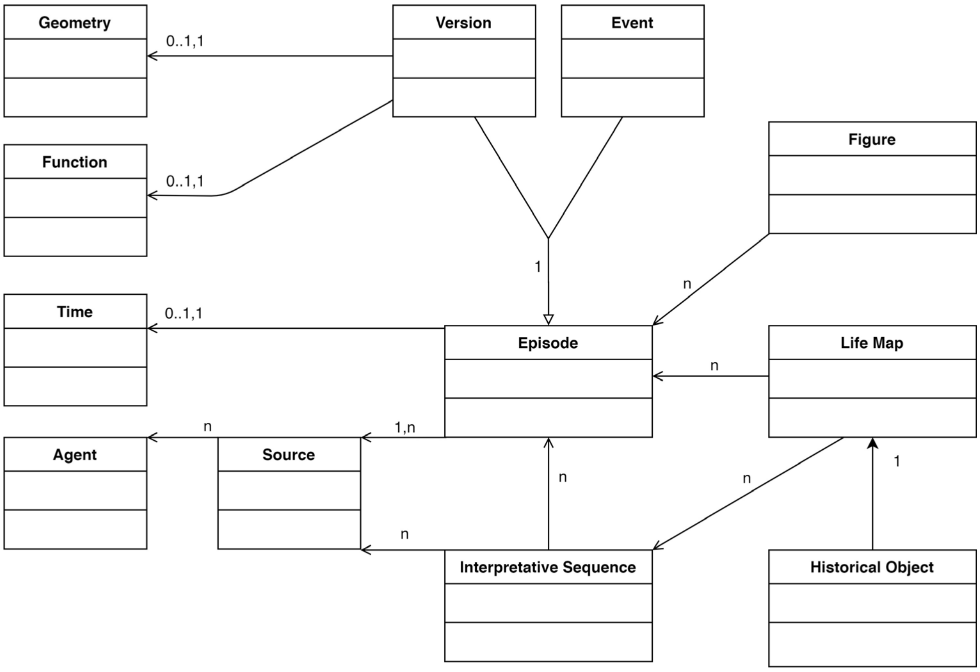

Figure 3 – The MIDM (Van Ruymbeke *et al.*, 2015).

In the MIDM, objects' lifecycle is documented through multiple key episodes of their existence, generated when modifications occur to one dimension (time, geometry, function). The 'Interpretation Sequence' class tackles the issue of uncertainty as it allows to document multiple interpretations of an object's history based on sources authored by different agents even if they overlap and contradict each other. It is worth precising that each interpretation sequence is constituted of non-overlapping episodes. Finally, the 'Life Map' class could be described as the object's timeline, as it "organizes all its episodes according to a chronological grid despite their involving, or not, into an interpretation sequence" (Van Ruymbeke *et al.*, 2015). The model was implemented in the CIDOC CRM ontology and compatible models (Van Ruymbeke *et al.*, 2017).

We propose to adopt and extend this data structure according to the specific needs of this research. Although 'function' seems here to refer to the use of objects, it is possible to consider other dimensions in the model to meet the requirements of specific projects/organizations. In this case for instance, new episodes can be created when changes to object's cultural significance occur.

3.4. Formalism

Unified Modeling Language (UML) is used for formal representation of knowledge, "representing static information using classes, attributes, and associations between classes" (Hug and Gonzalez-Perez, 2012). It is frequently argued that UML lacks specific aspects to deal with information from the humanities, often tinged with subjectivity and uncertainty. Although a Conceptual Modelling Language (ConML) compatible with UML has been developed to enable adequate representations of knowledge about the humanities" (Martin-Rodilla and Gonzalez-Perez, 2018), the issues of subjectivity, temporality and vagueness are directly addressed with UML in the MIDM. As we propose to extend the latter, the same modelling language is implemented here so extension proposals are coherent with the core model.

3.5. Metamodel

Figure 4 depicts the metamodel constituting the backbone of the extended MIDM and organizing its elaboration along three important steps based on the FKM. The first concerns the identification of features and their category, the second deals with their association with the cultural values they convey and the last concerns the definition of their DoS. For each phase, the main concepts will be analyzed and translated in a formal data structure, taking advantage on UML and based on deductive reasoning. The interest of the data model lies in its flexibility and in the cross-referencing of data it will enable. The idea is to identify and organize the necessary data to be encoded in a HIS to further enable the representation of key aspects of features' cultural significance through information retrieval and data analysis.

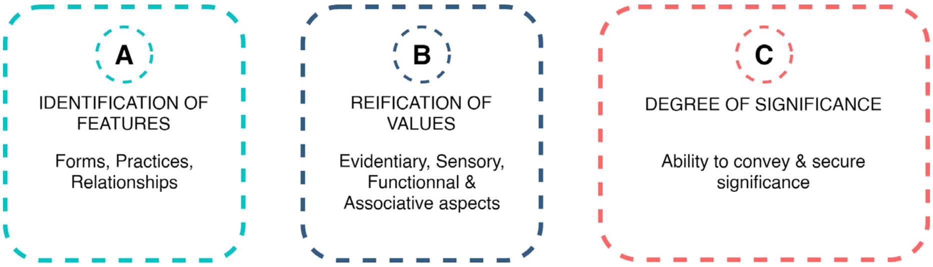

Figure 4 – The metamodel structuring the different sections of the data model.

4. DoS EXTENSION FOR MIDM

This research leaves aside the legal and administrative dimension of heritage designation as this aspect can be dealt with in a distinct module with a dedicated data model (Fernández Freire *et al.*, 2013; Myers *et al.*, 2016; Uriarte González *et al.*, 2014).

4.1. Extension A: *Identification of features of significance*

The elaboration of HIS implies the existence of one or several managing organizations and of at least one site to be managed and maintained. The class 'Site' refers to the place as an administrative entity and its identification in HIS comes prior than the objects it contains. As administrative boundaries might vary from an organization to another, objects potentially belong to several sites which spatial extent overlaps at the objects' location. A site therefore contains zero to many objects and an object can form part of one-to-many sites (Figure 5). As it is not possible to assess the significance of each individual component, the data model should enable the management of multiple scales. Instances of the 'Object' class could both be considered as a whole and as the constitutive part of other instances. Depicting the fact that objects can contain and be contained in at least one but potentially many (one to many) other objects, the reflexive association of the 'Object' class tackles this issue as it leaves the choice to the end-users to define the level of granularity of their HIS according to their needs and objectives. Features of significance belong to one of the three categories in Stephenson's model (forms, relationships, practices) (Stephenson, 2008). We replace the MIDM 'Historical Object' class, rather focusing on tangible archaeological objects, by a new 'Object' class to encompass both tangible and intangible features.

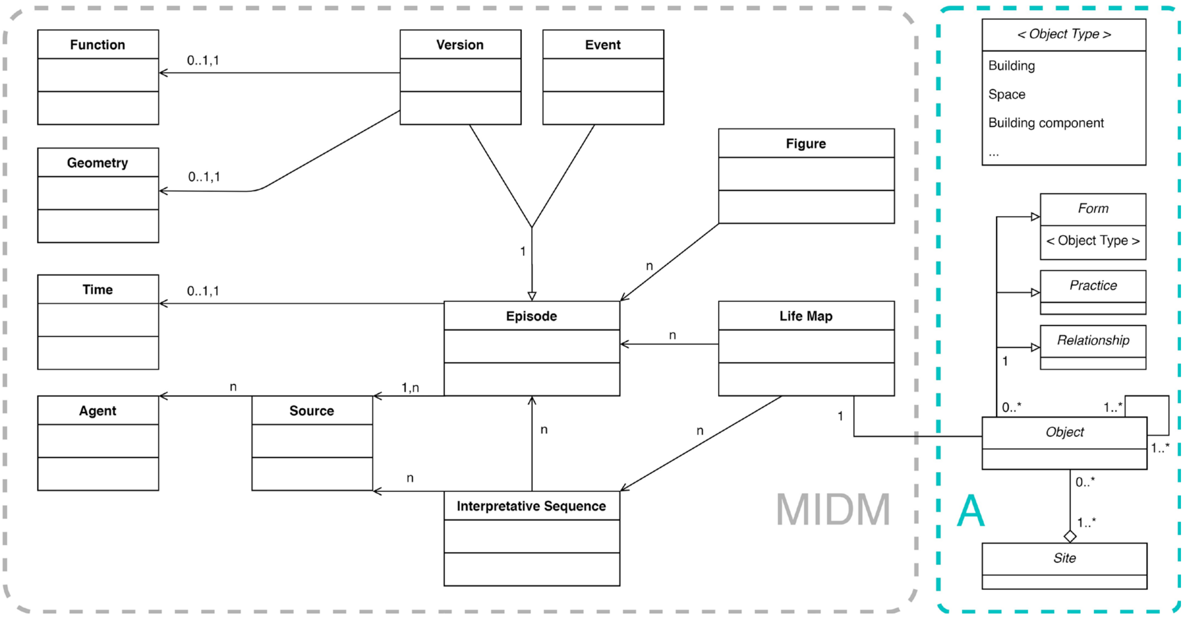

Figure 5 - The data model of the first phase (A) extends the MIDM and introduces the 'Object' class to include intangible features.

Some of the concepts proposed allow to glimpse a certain compatibility with the CIDOC CRM ontology and the Industry Foundation Classes. As highlighted by (Van Ruymbeke *et al.*, 2018), the CRMsci S15 class 'Observable entity' includes instances of the "E2 Temporal Entity or E77 Persistent Item" classes of the CIDOC CRM and is therefore pertinent with our definition of the 'Object' class. Concerning the link with IFC, objects belonging to the 'Form' Category can be related to a particular type such as a building, a space, a component, etc., and might then be related to entities of HBIM models by matching the 'Object Type' attribute to a specific IFC subclass (like IFCWall for instance).

4.2. Values reification

Value judgements representing the views of multiple agents (social groups, experts, groups of experts, etc.) can be extracted from sources of information related to the studied object (Figure 6). The analysis of these documents is performed by experts who identify, extract, select and validate pertinent values evaluating, among other factors, the context in which the data was collected, the expertise, role, and the degree of involvement of the consulted agent. Although a careful manual examination of the sources' content is required, data analysis software can support experts in this task (Prajnawrdhi *et al.*, 2015). These sources might present very diverse formats, varying from past formal statements of significance, interviews, surveys, reports of focus groups, collections of visitors' testimonies, written statements of experts, scientific publications, etc. In this regard, the potential of data extracted from people's opinions on social networks to provide with a kind of "social sensing" should not be neglected as it allows to explore the "general mood of a social community" (Amato *et al.*, 2017).

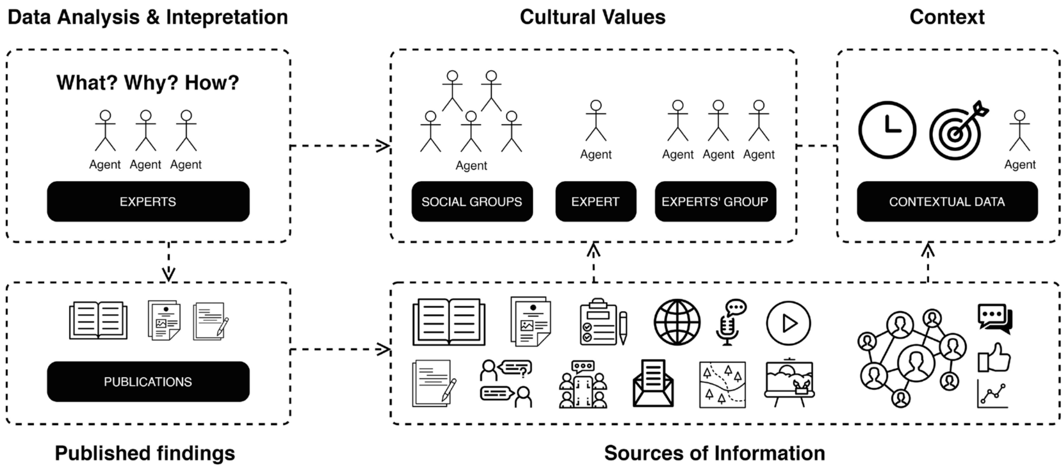

Figure 6 – This figure depicts the actors involved in the value assessment of CH and the sources of information used.

Contextualizing the collected data informs their interpretation by non-expert stakeholders and allows to highlight the need to review past assessments. *HIS should allow* keeping tracks of the successive values attributed along time to deal with the unstable aspect of values and to address the question of embedded values highlighted by (Stephenson, 2008). The data model should therefore integrate a "mechanism for reviewing and integrating past assessments" (Fredheim and Khalaf, 2016) to verify if elaborated guidelines for the preservation of places are still in line with present values. The Australian approach shows that statement of significance and subsequent recommendations for the management and preservation of assets can be updated either on a regular basis or in case of major interventions (Burke and Macdonald, 2014).

We propose to further extend the MIDM (Figure 7) by adding a new dimension to the 'Version' class so any value judgement documented in HIS generates a new episode in the object lifecycle. The 'Source' class allows to link such data to the document from which it is extracted and to provide key metadata about the value assessment context (objectives pursued, organization, agents involved, data collection methods, etc.). Finally, end-users can inform about the documents' authors and associated stakeholders through the class 'Agent'. The temporal dimension of value judgements is managed through the 'Time' class. The interest of this approach is in the level of granularity of the HIS enabled by the data model and the benefits it brings in terms of information retrieval. The encoding of such information indeed enables multiple representations of the significance of historical objects considering the views of targeted stakeholders, a given time frame, a set of objects carrying common values, etc.

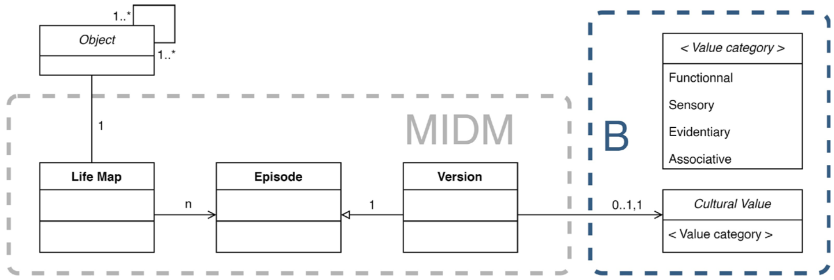

Figure 7 – A new class ('Cultural Value') is related to the MIDM 'version'. Zero-to-many cultural values can be associated to one-to-many objects. Each value is attributed with a specific value category among the four categories listed in the 'Value Category' enumeration.

4.3. Degree of Significance

To balance aspects of values with their actual importance for society, experts involved in conservation projects seek to determine how significant is the studied object regarding the values it carries using multiple qualifying conditions. Qualifiers are not values themselves (Fredheim and Khalaf, 2016), they rather affect either the importance, the validity, and the perceptibility of objects' significance. Analyzing their meaning and role in understanding and communicating about the objects' DoS, this section questions the potential of several qualifiers to support a quantitative approach for the integration of objects' cultural significance in HIS. While a first part focuses on the concept of rarity, underlying notions to the concepts of authenticity, integrity, and condition are discussed in a second phase.

4.3.1. Rarity

Rarity designates the unusual character of things that make them valuable and depends on their relationships with a set of other things belonging to a common type. Rarity, that refers to the fluctuating number of instances of a class composed by similar objects, increases objects significance since they progressively become one of the last remaining examples of a particular type. Although enabling the study objects' rarity within HIS would provide heritage organizations with explicit information about their significance, the dynamic and relative dimension of the concept should be considered.

Objects potentially belong to an infinite number of types depending on the perspective from which they are regarded. Rather than evaluating the overall rarity of features, experts aim at revealing multiple aspects of their rarity, comparing an asset with others sharing similar characteristics in their chronological and geographical dimensions as well as in other thematic layers like the cultural values they convey for instance. Rarity analysis can therefore hardly be automated and managing organizations must define specific aspects of rarity to be evaluated according to the nature of their asset and their objectives. Secondly, rarity is a changing notion as entities of a given type constantly fluctuates. Therefore, besides punctual assessments of rarity aspects, monitoring their evolution is important to identify problematic trends, like the sudden and rapid disappearance of a certain type of objects or simply when critical thresholds are reached. Both the absolute value of remaining objects of a type as well as the inflexion curve can be monitored in HIS. Such data allows to better understand and communicate about objects' DoS, revealing their uniqueness through the qualities and attributes that distinguish them from others. It would also give expert a quick insight into the potential need to re-evaluate the DoS of objects, and to implement preventive conservation strategies and protection measures to preserve particularly vulnerable or underrepresented categories of heritage.

The capacity of end-users to interrogate the system about objects' rarity depends on the granularity of the encoded data and on the possibilities that it offers in terms of data query. These query features can be implemented in the design of HIS' User eXperience (UX). The proposal presented here is pertinent in this regard, as any change to its temporal, spatial dimensions or to the thematic layers integrated generates a new episode in HIS.

4.3.2. Authenticity & Integrity

We distinguished four important aspects of authenticity/integrity assessment formalizable in a data structure.

- *Spatial-temporal continuity:*
  The goal of HIS is not to define the prism that should be considered to evaluate the authenticity and integrity of historical objects. However, HIS can play an important role in informing experts about their evolution along time. The extended MIDM presented in phase A allows to track the changes and document the evolution of both tangible and intangible features in all applicable dimensions.
- *Uncertainty of information sources:*
  The MIDM also connects sources of information and agents, identified as a crucial aspects of authenticity/integrity assessments (ICOMOS, 1994). Regarding sources of information used for the digitalization of the built heritage, (Jeanson et al., 2020) advocate the need to provide with contextual information related to geometry and information modelling activities. They insist on the importance to integrate information about the intent behind the documentation and the sources of information exploited. In section 3.3, it has been argued that the MIDM allows to manage this aspect through the classes 'Source' and 'Agent' as well as issues related to the uncertainty, vagueness, and incoherence (De Runz and Desjardin, 2010) of information sources by enabling overlapping interpretation sequences.
- *Aspects of Integrity:*
  Modifications to a site and its components potentially impact their ability to transmit certain values. Conservation strategies aim at managing the change while sustaining significance based on a clear understanding of the aspects of features impacting their ability to convey associated values. Arches platform (Getty Conservation Institute, 2021; Myers *et al.*, 2016) allows to associate significance evaluations to applicable aspects of integrity among which "Association, Design, Feeling, Location and Materials" . The approach adopted in (Croker, 2017) addresses this issue by integrating the concepts of Tolerance for Change (TfC) and Opportunities for Change (OfC) to provide future stakeholders with

guidance for the preservation of the valuable features. Besides the estimated TfC degrees, appended comments appear as the most operational elements as they clarify how the different aspects of the features impact the perception and transmission of associated values. We integrate this dimension by giving end-users the opportunity to inform about one or several aspects of integrity among an open list, and to provide with a description to avoid misinterpretations.

- *Condition & Vulnerability:*
  In addition to the concept of wholeness, Stovel argues that integrity analysis are also related to the idea of intactness, referring to the evolving condition and vulnerability of objects' physical realm. While the condition of value carriers impacts their ability to convey associated interpretations, present and future threats to their preservation challenge the ability to sustain the representation and transmission of these values. Though (Fredheim and Khalaf, 2016) argued that the deterioration of objects' condition "generally decreases … affected aspects of value", the contrary might as well be true like for emotional or sensory aspects of value associated to ruins. The type of impact it will have therefore depends on the nature of associated values.

Considering previous concerns, two additional dimensions to the 'Version' class allow to manage issues related to the condition and vulnerability of objects. Data can be extracted from condition and risk assessment conducted by experts to generate new episodes of an object based on major changes in its physical condition or on identified risks. Additional information can be added to estimate the risk's magnitude and associate one-to-many monitoring indicators. Finally, we add a new class to the 'Cultural Value' class to inform about one-to-many aspects of integrity (Figure 8).

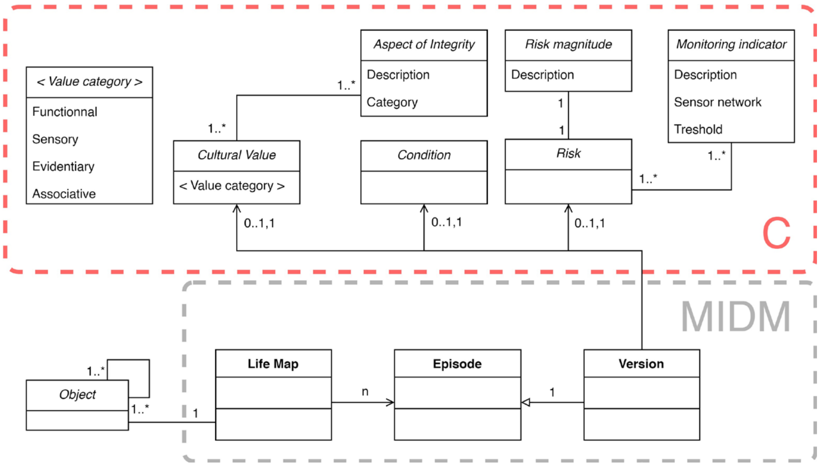

Figure 8 –This data model extends the MIDM to inform HIS about underlying notions to the concepts of authenticity and integrity.

4.4. Extension proposal for the MIDM

Figure 9 gathers all model parts in a single and coherent data structure. The proposal extends the MIDM to represent aspects of cultural significance in HIS. The extended MIDM allows to go beyond the historical dimension of objects in the data queries performed in HIS. Object's Life Map would provide with a global overview of all episodes generated based on changes occurred in each dimension of a version along time. For instance, figure 10 shows four distinct agents (Ag) informing HIS about different interpretation sequences (I.S.) representing episodes (Ep) with different temporalities and based on changes in different dimensions. All episodes would then together constitute the Life Map of the documented object and allow new interpretations (Figure 11) by other or even by the same agents. These new sequences could either consider multiple (Figure 11, I.S. 5) or individual dimensions (Figure 11, I.S. 6 & 7) depending on the objectives of the research. For instance (Figure 11, I.S. 6 & Figure 12), experts might investigate the different value judgements associated to an object during a given time frame. The data query might further be specified if experts are interested in understanding the significance of an object for a given social group along its lifecycle, highlighting the values extracted from a given source of information (So), identified by a specific agent, etc.

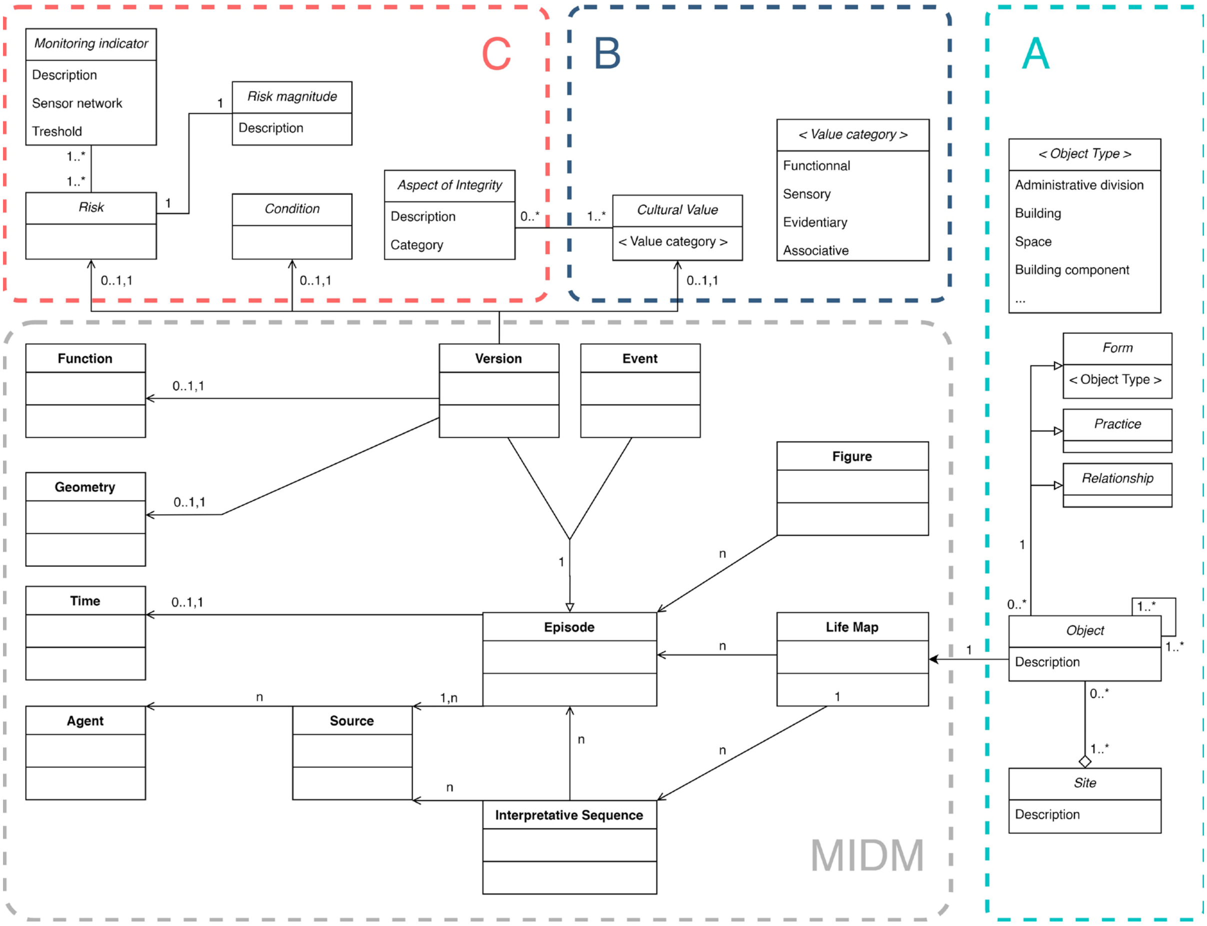

Figure 9 –The complete DoS extension for MIDM to enable the representation of diverse aspects of object's cultural significance in HIS.

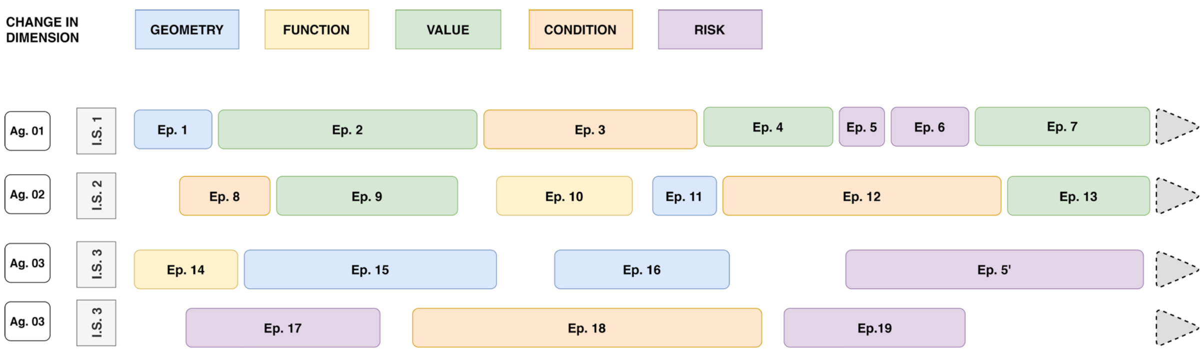

Figure 10 - Illustration of 4 agents informing about different interpretation sequences in HIS with multiple episodes documented along the temporal dimension. Episodes together constitute the Life Map of the object and allow to generate new interpretation sequences.

Figure 11 – This flowchart shows possible new interpretations based on episodes in the object's Life Map.

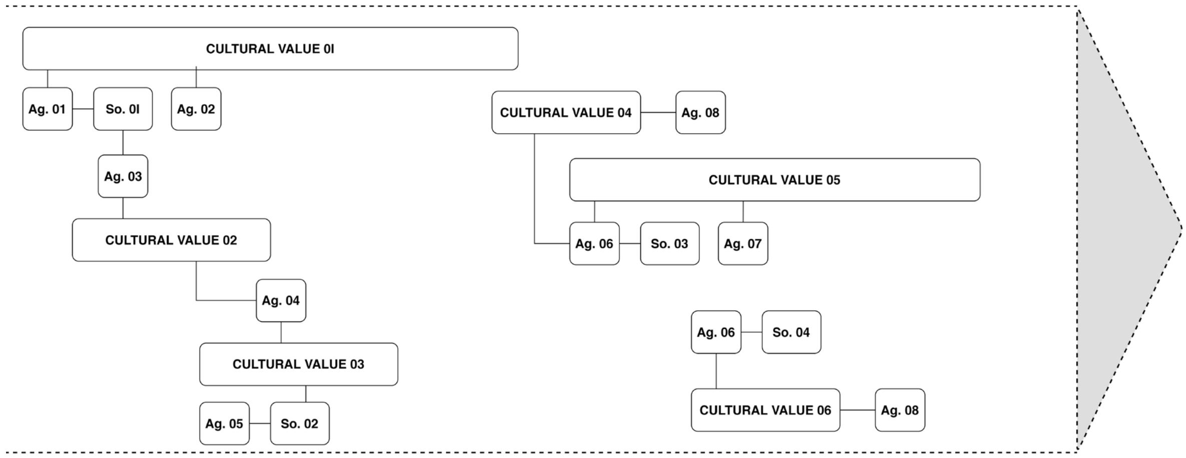

Figure 12 – This chart depicts the values associated to an object by multiple agents based on different source of information.

As represented in figure 11, thanks to the important data granularity enabled by the model proposed, HIS' end-users might retrieve tailored information about each dimension and compare with other objects sharing similar characteristics. The same figure shows that the comparison of multiple interpretation sequences allows to relate the evolution of one dimension with changes that occurred in others. These examples illustrate the model's potential to organize and centralize heritage information, to allow multiple and explicit representation of complex knowledge particularly concerning the values carried by historical objects and to support further comparative analysis, studies, and research.

5. Conclusions

Concepts related to cultural significance data are barely integrated in existing ontologies, data standards, data models and software developed in the field. This research assumes that a dedicated taxonomy would allow to inform about some aspects of objects' significance in HIS. To do so, key concepts have been analyzed to identify indicators of features' significance which enable quantitative representations of this dimension in HIS. The result is an extension proposal for the MIDM.

The model provides guidance for the elaboration of HIS and supports further studies and interpretations about meanings of the built heritage. It organizes the encoding of targeted data with a high level of granularity, and therefore allows to retrieve tailored information about objects' significance and to provide with multiple representations of this knowledge through specific data queries in HIS. The extended MIDM also enables studying different aspects of historical object's rarity trough comparative analysis in HIS considering multiple dimensions. Apart from its retrospective logic, the model enables simulating the evolution of objects, considering for instance their evolving rarity or the growing impact of deterioration processes on their condition. The extended MIDM therefore tackles issues related to stakeholder's involvement and collaboration along the conservation process and to the operational dimension of cultural values in decision-making processes. Ensuring a great flexibility in the representation of cultural significance data, the framework considers the dynamic aspect of significance assessments and the multiplicity of values associated to the built heritage.

This paper identifies several issues to be addressed in further research works. First, the different classes extending the MIDM have to be mapped onto the CIDOC CRM ontology and IFC standard to deal with interoperability issues and ensure the model' stability. Also, the implementation of the data structure for the elaboration of specific HIS is allowing to progressively refine the data structure along multiple iterations of the DSR process. Besides, we highlight the need to investigate the potential use of data extracted from social networks to capture the views of the public in a dynamic manner, and to evaluate the pertinence and value of such "social sensing' in the conservation process. Also, the use of tools dedicated to the analysis of qualitative data to extract key data about the significance of historical objects should be further examined. Finally, a comprehensive method for the collection of tailored information in line with the data structure proposed here will allow reducing the load work of experts responsible for the data encoding in HIS.

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