SEMANTICALLY DESCRIBING URBAN HISTORICAL BUILDINGS ACROSS DIFFERENT LEVELS OF GRANULARITY

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ABSTRACT:

Architectural, built heritage and historical buildings embody cultural heritage value and - as known - they need to be studied, documented, persevered and represented. Although there are many fields involved in these activities, none of these considered individually can fully represent the heritage with a complete level of detail and information. The present work aims to investigate the different levels of detail and granularity among different communities involved in historical buildings tasks to semantically define different concepts. In this context, ontologies are considered as an effective solution for the formal conceptualization of the domains involved, providing a common language for knowledge sharing and reuse. The study starts from existing knowledge (standards, vocabularies, thesauri, classifications) and conceptualisations for regional, urban and architectural heritage and geographic information for various tasks (restoration, documentation and heritage studies, risk prevention, heritage asset and facility management, education and tourism, urban planning and energy refurbishment/performance). A specific use case involving historical buildings in fortified centres across different levels of detail is described to show how existing knowledge and standards conceptualisation need to be integrated and extended.

1. INTRODUCTION

Historical and heritage buildings, which are part of the historical centres and historical urban landscapes, embody both cultural heritage values and city configuration features. For this reason, in the past, historians, urban designers and planners, and conservators have acknowledged great importance to the documentation of those buildings, which are often expressions of identity and intangible cultural values for both the local and further communities.

The study and the preservation of cultural, architectural and built heritage is supported by many processes. Each of them would require specific multidisciplinary data, involving a lot of actors from different application areas, communities and domains. Therefore, a great advantage could come from the use of a common language allowing data re-use and integration and knowledge sharing. In this sense, ontologies are considered as an effective solution for the formal conceptualization of a domain. Ontologies facilitate knowledge representation and semantic description of concepts with their attributes and relations. Sharing a common understanding and exchanging information among different users is one of the main ontologies goals (Musen 1992; Gruber 1993).

There are many reasons why the development of an *ontology of historical buildings* could be useful. First of all, since historical buildings have cultural values, they need to be protected and documented. Moreover, plans for restoration, planning in historical cities and urban policies could benefit from a common language and structure of knowledge information accessible to all the actors involved.

However, although there are many fields and communities involved in activities and tasks concerning the historical centre and built heritage, none of these expertise and knowledge domains considered individually can fully represent the heritage with a complete level of detail and information.

Therefore, before starting the definition of concepts and relationships in the domain of *historical built heritage*, it is necessary to clarify the *scope* of the ontology design in this context. For this purpose, this study proposes an investigation of some possible use cases to show how different communities could answer to different competency questions (Gruninger & Fox, 1995) based on various needs. This will prepare the necessary ground for the development of a common ontology.

Over the years some studies have made attempts to define cultural and built heritage domain ontologies. The core ontology for managing cultural heritage information is the CIDOC conceptual reference model (CRM), standard ISO 21127. It structures high-level concepts, so it is largely used to underlie interoperability in cultural heritage domain (including architectural and landscape heritage). This is the base of several

studies (Moraitou et al., 2019; Häyrinen, 2010; Kokla et al., 2019), which are further detailed in Section 2.1.
In addition, it is important to mention the research methods and tools made in the field of geographical and spatial information and modelling to manage and document cultural and architectural heritage. For example, extensions of the Open Geospatial Consortium (OGC) CityGML standard were proposed (Noardo, 2018; Mohd et al., 2017; Egusquiza et al., 2018), as well as of the INSPIRE data model (Chiabrando et al., 2018; Fernández-Freire et al., 2013).
Recently, the use of HBIM technology was proposed for boosting the interoperability in the management of preservation plans in cultural heritage: e.g. cloud-based platform enhancing metadata and semantic-based search to access open data (Brumana et al., 2019); operational proposals aiming at the demonstration of the usefulness of ontological approaches in semantic-based representation of buildings or important components of them (Niknam & Karshenas 2017; Previtali et al. 2020).
Despite this aforementioned research a lack in the nowadays scenario is still present. As for the field of geographical and spatial ontologies, a structure for properly semantically describing *buildings of historical fortified centres* is missing.
A stronger link between these two fields could be valuable for allowing the re-use of existing information for cultural heritage studies and preservation actions support. Moreover, the semantic formalisation of interrelated concepts is important to identify, analyse and manage specific historical and heritage buildings with spatial domain ontologies.
The present paper proposes a literature investigation of the semantics of built heritage, historical buildings, fortified structures and castles across different levels of granularity, different use cases and communities (§2). Definitions from existing standards, classifications and conceptualisations have been analysed and compared to be the base for the semantic formalisation of fortified structures in historical centres (§3). This step is necessary to foster the re-use of the already structured systems and datasets, comparing similar concepts and terms to avoid inconsistencies among users and ontologies. Afterwards, based on the aforementioned analysis, the use case of *urban historical, heritage buildings spatial and geographical features documentation* was chosen to compare and assess existing conceptualizations.

2. STATE OF THE ART: HISTORICAL BUILDINGS DOMAIN

Although there are no existing ontologies designed to represent historical buildings and fortified structures, there is a wealth of knowledge from existing legislation, vocabularies and standards that provide some classifications and definitions in the domain of cultural and architectural heritage.
With this in mind, we considered performing a literature investigation to extract semantic information from different types of useful sources: semi-structured data (natural language texts), already defined data in codified/standardised language, thesauri, vocabularies, list of terms, etc.
The existing standards for the representation of built, urban and architectural heritage knowledge come from various fields. Some of the most critical ones are those available for digital mapping, which is essential to represent the architecture in its context and the cultural heritage, describing data about history, cultural value, artistic characteristics and further relevant connected issues. The next Sections consider the main standards in the fields of *built heritage and geographic information*.

2.1 The architectural heritage representation: national and international standards, vocabularies, thesauri and linguistic ontologies

Besides the UNESCO and ICOMOS standards already studied in (Kokla et al., 2019) for the historic urban landscape and town definition, the present work considers the CIDOC-CRM standards. The International Committee for Documentation (CIDOC) of the International Council of Monuments (ICOM) developed the standard core ontology for representing CH: the 'CIDOC conceptual reference model' (Doerr et al., 2007). It was born for the representation of the knowledge of museum objects and it is applied in architecture, archaeological heritage (De Roo et al., 2013).
Some extensions were developed to improve the usability of the CIDOC-CRM for the different domains and typologies of CH such as the 'Monument Damage Information System' (MONDIS) (Blaško et al., 2012; Cacciotti et al., 2013). The *CRMgeo*[1] (Hiebel et al, 2015) integrates spatiotemporal properties of temporal entities and persistent items. With this aim, it connects the CIDOC CRM to the OGC standard GeoSPARQL. The latter intends to represent and to query geospatial data on the Semantic Web, its structure defines the geo-classes *Spatial Object*, *Feature* and *Geometry*. Then, the *CRMba*[2] (Ronzino et al., 2016) encodes metadata about the documentation of archaeological buildings; the *CRMarcheo*[3] (Doerr et al., 2020) supports the archaeological excavation process and all the various entities and activities related to it and the *CRMsci*[4] (Doerr, 2018) is a formal ontology intended to be used as a global schema for integrating metadata about scientific observation, measurements and processed data.
In the framework of heritage classification, the Getty Institute Vocabularies propose terms connected to CH, intending to categorise works of art, architecture, material culture, the names of artists or architects as well as the geographic categories. One of these, considered for the present research, is *the Art and Architecture Thesaurus* (AAT). Terms in AAT may be used to describe art, architecture, decorative arts, material culture, and archival materials. The target audience includes museums, libraries, visual resource collections, archives, conservation projects, cataloguing projects, and bibliographic projects[5].
Moreover, due to the richness of the Italian national cataloguing and classification of CH entities, we chose to consider and to study also some works belonging to the "Ministero per I Beni, le Attività Culturali e il Turismo" (MIBACT). It developed a structured classification defined by the Italian Central Institute for Catalogue and Documentation (ICCD) aimed at the documentation and preservation. It is implemented in the SIGECweb platform[6], and some efforts for mapping this classification to the standard CIDOC-CRM ontology are in progress. To guarantee the practical use of this classification and its interoperability, some specific ontologies have been designed[7]. The first example is ArCo, the Knowledge Graph of the Italian CH and consists of 7 vocabularies describing the CH domain. Secondly, the Cultural-ON ontology[8] aims at modelling the data that characterize cultural places, such as data on entities or people who have a specific role on institutions and cultural places, the physical locations of the places, the multimedia that

[1]http://www.cidoc-crm.org/crmgeo/home-5
[2]http://www.cidoc-crm.org/crmba/home-7
[3]http://www.cidoc-crm.org/crmarchaeo/
[4]http://www.cidoc-crm.org/crmsci/home-1
[5]https://www.getty.edu/research/tools/vocabularies/aat/about.html
[6]http://www.iccd.beniculturali.it/it/sigec-web
[7]http://www.iccd.beniculturali.it/it/per-condividere/interoperabilita
[8] http://dati.beniculturali.it/cultural_on/

describe an institute and place of culture. Finally, in the area of fortified structures and castles, the Glossary of "Istituto Italiano dei Castelli" collects terms related to fortified architectures[9].

2.2 Existing standards of Geographic Urban and Buildings Information

In the field of geo-information there are many standards. CityGML[10], published by the Open Geospatial Consortium (OGC), is probably the most internationally acknowledged standard data model for representing multiscale 3D information about cities. Secondly, there is the data model defined by the European Directive for an Interoperable Spatial Data Infrastructure in Europe (INSPIRE)[11] (published in 2007 and to be compulsory adopted in every European Country by 2020). The INSPIRE standard aims at the representation of homogeneous cross-boundary data to support environmental analysis in Europe. It includes in its "buildings" data model part some features inspired by the previous CityGML ones.
As concerns architecture, engineering and construction, as well as asset and facility management, the building SMART Industry Foundation Classes (IFC) are the designed standard for Building Information Model (BIM). It aims at the representation of information related to the design of new buildings, generally using parametric modelling.
Combining semantic web-based technologies and the consequent ontological approaches with the AEC (Architecture, Engineering and Construction) industry seems also to be increasingly pursued (Pauwels et al. 2017).

3. METHODOLOGY

This study analyses different cultural heritage use cases and incorporates different levels of granularity (region, built heritage, buildings, ...) within the ontological process design (§ 3.1), to select a reference list of questions that this ontology could answer.
According to the Ontology Guide by (Noy and & McGuinness, 2001) some examples of competency questions may include the followings:
- What type of historical buildings is it?
- Where is it located?
- What was/is its function?
- What are the (physical/health) conditions of the considered historical heritage?
- Does it need any restoration actions?

3.1 General reasons motivating the use of ontologies

Among the aims and scopes towards the development of a thematic ontology for historical buildings we suggest the following three main reasons:
(1) As mentioned in (Noy and & McGuinness, 2001), the reuse of existing knowledge is a crucial step in the ontology creation approach. It allows the *exchange of information* among stakeholders involved in different tasks of an application. Hence, the main reason to design an ontology arises from the fact that, despite there are many existing ontologies in the domain of CH, they don't answer to the needs of documentation of historical buildings and fortified castles. This reason will be motivated in the methodological part of the present work (§3), comparing domains and users and trying to underline the motivations why they are not sufficiently structured or developed for historical structures. Relevant and general concepts have been extracted from this already structured knowledge.
(2) A second possibility regards the study of the already existing domains (as well as architecture, history, architecture and places, geography, urban design and planning, …) and their *different conceptualisation to define information* using their own ontology. Therefore, after having analysed possible inconsistencies among different conceptualisations about historical buildings, the study aims to lay the foundations for possible *ontology alignment, mapping or integration*. The integration of different ontological structures is a crucial point for the reuse and exchange of knowledge among different domains (Kavouras & Kokla, 2007).
(3) The third reason is related to the current scenario of *massive data availability and technology innovation*.
Today, with the wide availability of spatial 2D and 3D data, major heterogeneities occur at different levels (data formats, logical models, definitions, etc.). In this framework, geographic domain ontologies could support many processes, such as the extraction of useful information, the recognition of historical monuments, the automatic segmentation and identification of parts of buildings and cities and so on.
Existing ontologies usually address one specific level of detail, with various granularity, for the present work we choose to develop a structure that could represent a more holistic view of the domain of historical city and buildings. Table 1 shows a few examples of different levels of representation related to the existing ontologies or models.

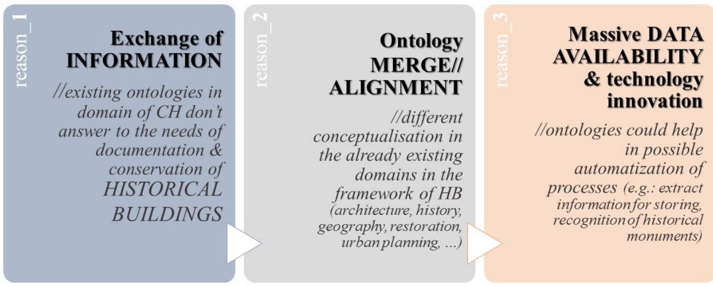


Figure 1. General reasons and scopes for an ontology creation.

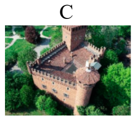
Levels of representation	Relevant aspects	Existing ontologies/models
A 	Territory Landscape Regional features	Spatial ontologies *(e.g.: GEOSPARQL, INSPIRE)*
B 	City and city parts (city walls, roads, squares, boundaries, buildings, …)	Urban planning ontologies City ontologies *(Towntolg* - Teller et al., 2007-, *CityGML)*
C 	Building and building parts Buildings architectural and structural elements	CH (CRMba) & Architecture ontologies (CityGML, IFC) Archaeological ontologies (CRMarcheo)

Table 1. Level s of detail in the domain of CH.

[9]http://www.istitutoitalianocastelli.it/risorse/supporti-scientifici/11-supporti-scientifici.html

[10] http://www.opengeospatial.org/standards/citygml
[11]http://inspire.ec.europa.eu/data-model/approved/r4618-ir/html/

3.2 Communities and use cases in the domain of historical building

The systematic use of ontologies, besides the possible technological advantages, supports the representation of the exact information needed in operational use cases. Therefore, in the following, we consider how they can be helpful for stakeholders and actors to provide information for a couple of specific tasks.
On the base of official documents stating the value and needs of cultural and architectural heritage (as well as UNESCO conventions[12] and CH European documents[13]), a couple of specific use cases for an ontology representing historical buildings and fortified structures were identified and explored. Moreover, the "sustainable development goals" of the 2030 agenda defined by the United Nations[14] were considered to verify refurbishment/performance. These use cases involve different communities and the CH assets that are taken in charge have to be considered accordingly to a complex grid of parameters depending on the roles of the actions undertaken and the level of granularity (territorial/ landscape level; urban level; architectural level and higher scale ones concerning components of architectural complex or movable heritage) that need to be considered.

The next figure 2 suggests the complexity of the plots and relationships that need to be considered.
For each of them, we reviewed the specific efforts already intended to provide ontological structures, conceptualizations and vocabularies, trying to assess their state of implementation and the need to develop them further. In Table 2 for each of the use cases, we specified examples of the questions which could be effectively answered by an ontology, considering the three reasons represented in Figure 1 and explained in the previous section 3.1. Moreover, the useful levels of detail and granularity of the ontology are defined, as well as the involved stakeholders.
Conservation is probably one of the most investigated use cases, with several studies already proposing solutions and extending the official ontologies such as the CIDOC-CRM (Tait, While, 2009; Acierno et al., 2017; Acierno et al., 2019; MONDIS ontology, described in Blaško et al., 2012 and Cacciotti et al., 2013). In particular (Acierno et al., 2019) proposes an ontology for the historical centre conservation and management.

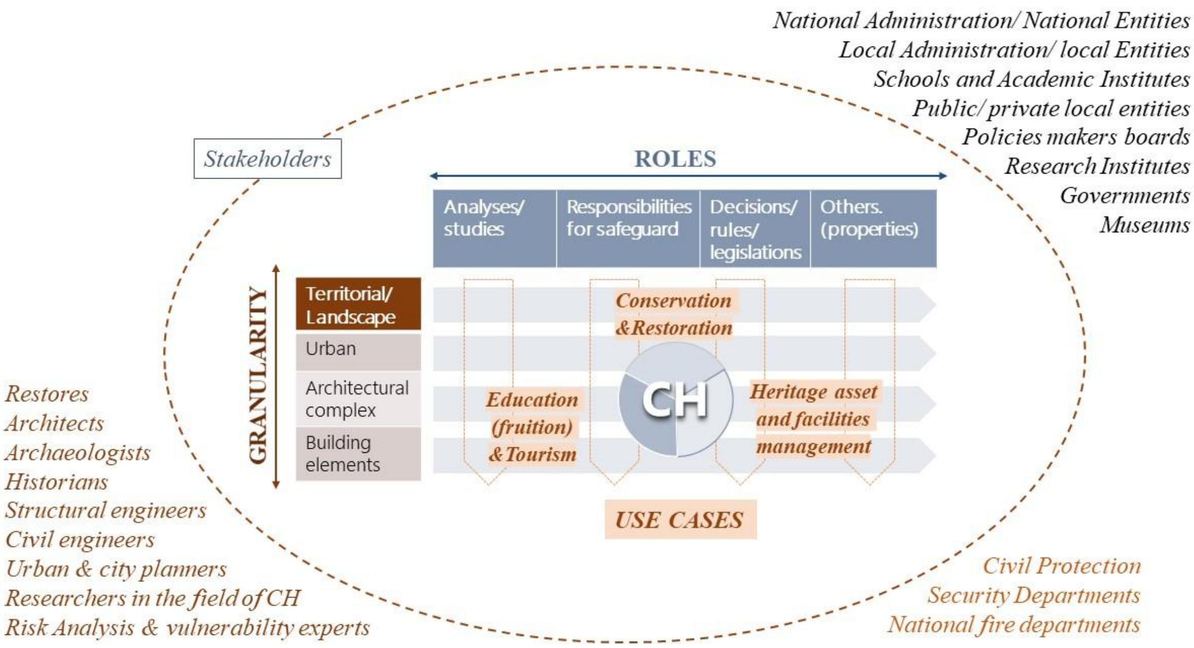


Figure 2. A possible graphical view of communities involved in specific use cases and the grid of parameters concerning roles and granularity considered in the complex action undertaken in CH domain

*Documentation and heritage studie*s is not an unexplored domain either (e.g. Hois et al., 2009 about the architectural and built heritage and also the more general heritage conceptualizations consider this as one of the most important goals), but a lot of potential about specific developments is still there. Regarding heritage *risk prevention,* not an ontology, but a specific data model was proposed starting from standardised structures and vocabularies within the ResCult project (Chiabrando et al., 2018).

The same is true for energy refurbishment of historical centres and buildings, for which an extension of CityGML was proposed (Egusquiza et al., 2018). For *urban planning*, some examples exist, mainly related to the representation of the city without a specific focus on historical aspects (e.g. the Towntology project, Teller et al., 2007; Berdier & Roussey, 2007).

[12]http://portal.unesco.org/en/ev.php-URL_ID=12025&URL_DO=DO_TOPIC&URL_SECTION=-471.html

[13] https://whc.unesco.org/en/documents/

[14]https://sustainabledevelopment.un.org/?menu=1300

Use cases/domains	Specific questions at which the ontology can effectively answer	Useful level of detail/granularity
1. Restoration	- Is it affected by surface, functional or structural damage or deterioration? - Are similar cases of damage documented? How was it treated in those cases? - What are the main causes of the damages? - May I identify the specific elements on which deterioration occurred? Which related elements are probably affected too?	*Geometric:* Buildings and building parts, architectural elements *Semantic:* Built heritage, historical buildings, fortified structures
1.1 Documentation and heritage study	- What is the typology of the historical building? - What sources (documents, conventions, standards, ontology) describe it? - Is there other cultural heritage connected with the considered building?	*Geometric:* Cities, buildings, Building parts *Semantic:* Cultural heritage, architectural heritage, historical cities, historical building, fortified structure
1.2 Risk prevention	- Is it damaged by hazards? If yes, what kind? - Is it located in an at-risk area? Are there existing maps or documents describing possible or occurred risks?	*Geometric:* National area, regional area *Semantic:* Territory, landscape heritage, building, historical buildings, cultural heritage
2. Heritage asset and facilities management	- Is it public or private? - Who is delegated to manage the heritage?	*Geometric:* Cities, buildings, building parts *Semantic:* Cultural-architecture-built heritage, historical buildings, archaeological sites, museums
3. Education (fruition) & Tourism	- Has the heritage a cultural value? - What type of heritage is it? - Is it related to other tourist attractions? How are these valorized? - Is there a digital reconstruction/representation of the heritage?	*Geometric:* Cities, parts of city, buildings *Semantic:* Territory, landscape (cultural), architectural heritage, historical buildings, archaeological sites/heritage
4. Urban planning	- What is the context of the historical building/fortified structure? Are there other buildings connected to it? - What urban plans involved this historical centre in the past?	*Geometric:* Cities, buildings *Semantic:* Cities, urban city core, historical city, historical buildings
5. Energy refurbishment/performance	- In what year/period was it built? - Is there an energy system? Who installed it? What type is it? - Is there a BIM model or digital model of that building?	*Geometric:* Cities, parts of the city *Semantic:* Buildings, architectural elements, buildings energy system

Table 2. Table 2. Use cases, related specific questions and levels of the granularity.

4. RESULTS

After having analysed the possible use cases, we chose to focus our attention on the **documentation and heritage study**. Since it represents a huge area of research that involves many experts and disciplines (as well as historians, cataloguing entities, heritage management,), we looked at the even more specific use case of "*urban historical, heritage buildings spatial and geographical features documentation"*. Therefore, the attention is focused on concepts and aspects useful to geometrically document and digitally represent the built heritage (through different methods and techniques such as GIS, 3D city models, BIMs). In this regard, the outcomes here presented, analyse the concepts of *historical buildings in fortified centres* for different levels of detail and relate them to the existing conceptualizations.

4.1 Comparison between existing conceptualisations

The semantic formalization of such historical buildings and fortified settlements (Figure 3) requires numerous semantic categories and rules describing specific components and related aspects (year of construction, ownership, materials, and so on), the particular shape and features of their components and their mutual relationships. The considered aspects also vary in scale, encompassing both the small components of the building, as well as elements of the wider area including the historical city and the landscape. These elements are an important part both for the recognition of the building's importance and role, and for constituting the landscape itself (towers, moats, adjacent squares, city walls, streets system, and so on).

In this framework, different conceptualisations have to be analysed, to investigate what are the already defined classes with their definitions (Kokla, et al., 2018), starting from the available ontologies, standard data models and vocabularies to define the concepts, properties, relations and rules which may be used to relate to this existing knowledge. It will be necessary to assess which of the available schemas will be the most suitable ones, or likely use several of them connected, analysing them and individuating possible heterogeneities.

Then, one of the results of the present work underlines some inconsistencies or gaps among the existing conceptualizations. Some already spread possible standards (explained in §2) for cultural heritage documentation have been selected in increasing levels of detail (with different granularities): ICOMOS, UNESCO, the CIDOC-CRM and GEOSPARQL ontologies, the conservation-ontologies by (Acierno et al., 2017, 2019), the GETTY AAT Vocabulary, the CityGML model and the IFC structure.

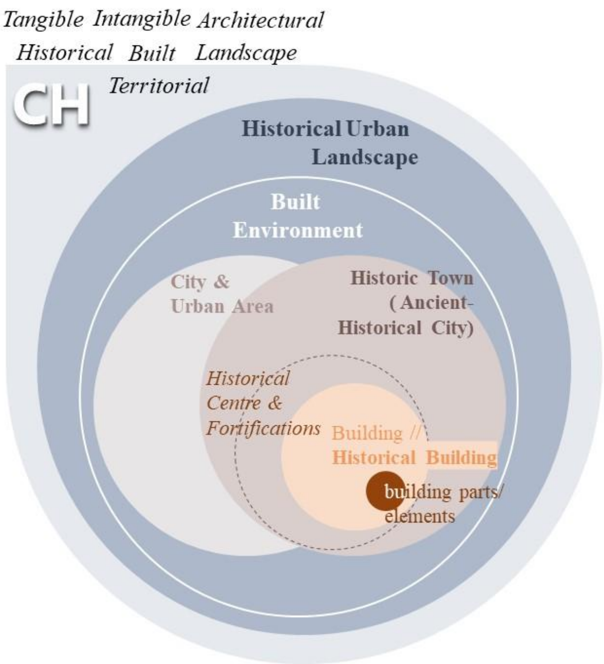


Figure 3. Figure 3. Some classes/spatial objects and relations based on standards definitions and spatial dimensions and characters.

After comparing the concepts representing historical building (HB) and fortified settlement (FS) in the different conceptualizations, with different levels of detail and granularity, we carried out a schematic view (Table 3) that show how existing knowledge and standards conceptualisation have to be integrated and extended. The main issues are reported in column *Remarks*, based on the following points:

- Typology of conceptualization;
- Concepts related to HB;
- Formal/non-formal representation;
- Level of representation: A B C (see Table 1);
- Granularity;
- Explicit spatial concepts.

5. CONCLUSION AND FUTURE PERSPECTIVES

In this paper, we have discussed the necessity of the development of a common ontology for historical centres with a focus on the use case of documentation and study of CH. This outcome is the result of a deep investigation in the nowadays framework of the many levels of granularity of standards and conceptualizations for urban historical buildings and their geographical features.
Thanks to this study it was possible to underline the heterogeneity of knowledge among different communities.
A possible future scenario could consider further steps of the ontology design, both with top-down and bottom-up approaches to define classes, entities and relations in the domain of HC.

Existing knowledge	Application area	Concepts Related to *Historical Buildings*	Definitions (with different levels of detail)	Remarks
ICOMOS	CH	Historic Town and Urban Area	*evolution of a society and of its cultural identity*	- global knowledge - there aren't concepts of HB & FS - level of representation A/B - no formal representation/only natural text language - no sufficient granularity - no spatial information
UNESCO	CH	Ancient city → Historic city	-	- global ontology - historical centre are considered - level of representation A/B - no formal representation/only natural text language - no sufficient granularity - no spatial information
		Historic Urban Landscape	*the urban area understood as the result of a historical layering of cultural and natural values and attributes*	
		Historical Centres	*centres comprising a considerable number of cultural heritages called "monumental centres"*	
CIDOC-CRM core	CH	Man-Made Thing → Physical Man-Made Thing → Man-Made Object	*physical objects purposely created by human activity*	- domain ontology - concepts of HB & FS don't exist explicitly - level of representation A - ontology and related formal representation - some levels of granularity are represented - location information is included
		CRM Entity → Observable entity → temporal entity → State → Condition State	*states of objects characterised by a certain condition over a timespan*	
		Physical Feature → Site	*pieces of land or sea floor*	
		CRM Entity → Place	*extents in space*	
CRM archeo	archeological excavations	Matter Removal → Observations → Archaeological Excavations	*general concept of archaeological escalation intended as a coordinated set of excavation process units*	- domain ontology - there aren't concepts of HB & FS - formal representation - detailed level of concept and relations (A/B) - some levels of granularity are considered/possibility for ontology extension with other CIDOC-CRM ontologies - geographic query language
GEOSPARQL	SI	Spatial Object	*it represents everything that can have a spatial representation. It is superclass of feature and geometry"*	- geographic query language - there aren't concepts of HB & FS - already integrated in the CIDOC-CRM geo
		Geometry	*it defines a vocabulary for*	

			asserting and querying information about geometry data, and it defines query functions for operating on geometry data	- many levels of detail are considered (A/B) - no levels of granularity are represented - useful for a spatial documentation
		Feature	*it represents everything that can have a spatial representation. It is superclass of feature and geometry*	
CRM geo	SI	Information Object → Geometric Place Expression	*definitions of places by quantitative expressions*	- domain ontology - concepts of HB & FS don't exist explicitly - formal representation - some level of granularity - detailed level of concept and relation - useful for a spatial documentation
		Place → Declarative Place	*instances of places*	
		Spatial Coordinates Reference System	-	
		Phenomenal Place	-	
CRM sci	scientific knowledge	Observation → Measurement	*actions measuring instances*	- domain ontology - concepts of HB & FS don't exist explicitly - not enough granularity - formal representation - specific for documentation
		Observations	*activity of gaining scientific knowledge about particular states of physical reality through empirical evidence, experiments and measurements*	
CRM ba	archaeological buildings	built work → single built work	*buildings, components of buildings, and complexes of buildings. It refers to man-made environments*	- domain ontology - concepts of HB & FS don't exist explicitly - formal representation/detailed level of concept and relation - level of representation B/C - some level of granularity
(Acierno et al., 2017, 2019)	conservation & restoration	Historical centre → **Historical Buildings**	-	- application ontology - concept of HB does exist explicitly - formally expressed - restoration purposes - no high level of granularity
		Artefact_Entity	-	
GETTY AAT Vocabulary	art and architecture	built environment	*constructed works and natural landscapes*	- thesaurus - concept of HB does exist explicitly - level of representation A/B/C - high level of granularity - very detailed definitions of concepts - formally represented - no spatial concepts
		built environment → settlements and landscapes → cities	*Distinctions among villages, towns, and cities are relative and vary according to their individual regional contexts*	
		Tangible cultural heritage → architectural heritage	*Built works transmitted intergenerationally within a society and that are invested with significance in that society.*	
		single built work (built environment) → **historic building**	*buildings that are significant in the history of architecture*	
		single built work (built environment) → monuments → **historical monuments**	*monuments with local, regional, or international political, cultural, or artistic significance*	
		single built work (built environment) → fortifications	*General term for any works made to oppose a small number of troops against a greater*	
		fortified settlements	*Settlements of any kind with defensive structures such as moats, enclosures, or ramparts*	
CityGML	cities and buildings (GIS)	CityObject → Site → AbstractBuilding → Building	*It allows the representation of thematic and spatial aspects of buildings, building parts and installations in four levels of detail, LOD1 to LOD4*	- conceptual model - concept of HB does not exist explicitly - formal representation - level of representation B/C - different levels of detail for buildings representation - formally represented - not intended for heritage - spatial knowledge is included
		Building → Building parts		
IFC	buildings and buildings part (BIM)	IfcSite → IfcBuilding	*A building represents a structure that provides shelter for its occupants or contents and stands in one place*	- concept of HB does not exist explicitly - level of representation C - spatial knowledge is included - formal representation - not intended for heritage - high level of granularity/detail - spatial knowledge is included
		IfcSite → IfcBuilding → IfcBuildingElements	*The building element comprises all elements that are primarily part of the construction of a building*	

Table 3. Heterogeneity of existing knowledge and standards conceptualisations-

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