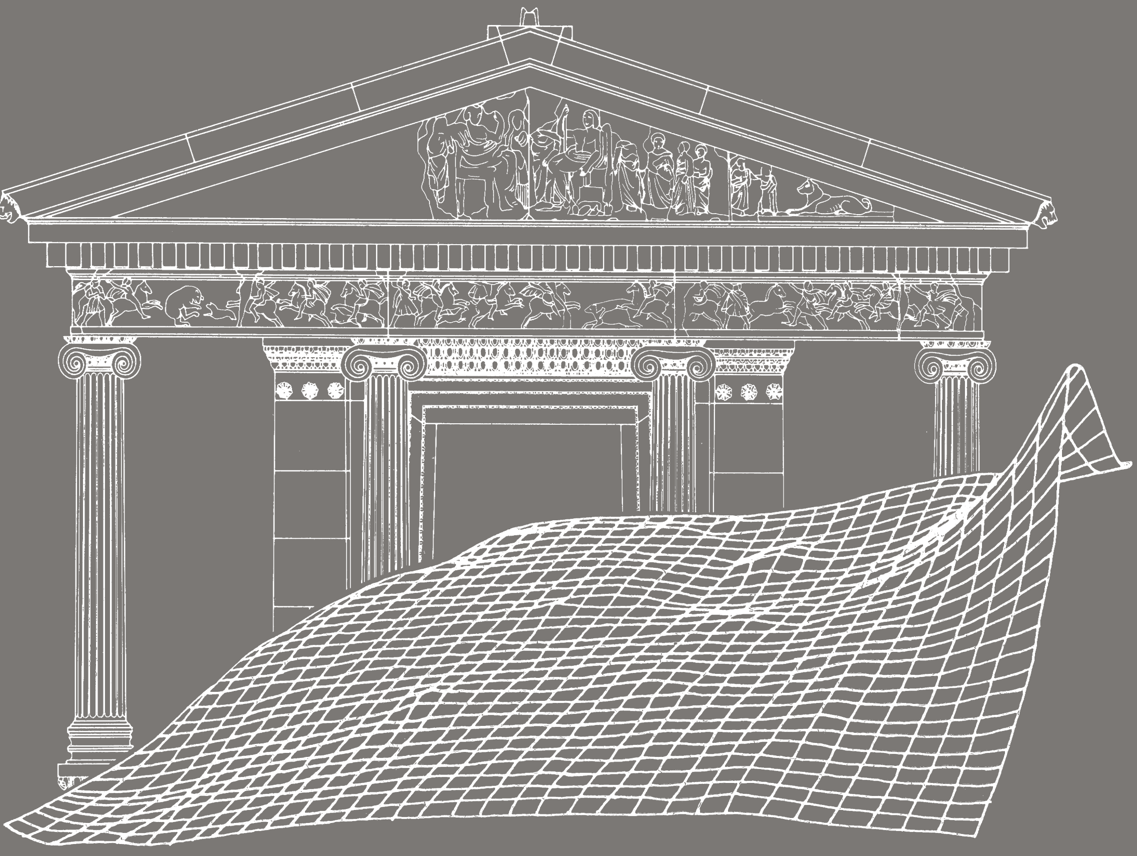

ARCHEOLOGIA E CALCOLATORI

36.1

2025

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ARCHEOLOGIA E CALCOLATORI

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BIM AND GIS INTEGRATION: PLANNING A DIGITAL APPROACH TO ARCHAEOLOGICAL SITE MANAGEMENT

1. Introduction

The Vesuvian area is rich in large archaeological sites of great cultural interest[1]. The complexity of these sites derives above all from their considerable extension and strong links with the surrounding contemporary urban fabric, as well as from the enormous number of documents and data collected from the excavation phases to subsequent studies. Areas such as Pompeii, Herculaneum, Stabiae, require particularly articulated digital archives, capable of containing and managing information at different scales and of different interest, ranging from knowledge to maintenance, from security to communication.

These world-renowned sites are also notable for featuring a layout that is uncommon in archaeology: architectures that are almost entirely preserved and complete; the Pompeii Archaeological Park is an outstanding example of this configuration. Consequently, to plan maintenance and conservation of such an exceptional place, the integration of many large datasets, updated constantly and enriched with spatial information is crucial. The success of the PRIN competition (Research Projects of National Interest, funded by the Italian Ministry of University and Research) in 2022, with the project titled 'BIG_SMAART - BIM & GIS for Spatial and Multidimensional Archaeological Artefacts and Techniques', provided the ideal opportunity to develop a comprehensive plan to tackle this integration issue. The project's goal is to establish a system that assimilates past digitization and research efforts, with the objective of systematizing and utilizing these insights for the future preservation and advancement of the ancient city. The interoperability issue lies between different frameworks, applied to the field of archaeology, namely the realm of BIM (Building Information Modelling) which deals with information at the architectural level and GIS (Geographic Information Systems) which deals with spatial information. By studying integration within BIM and GIS databases, the project aims to consolidate data types and allow for automatic,

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[1] Authorship contribution statement: Olga Rosignoli: writing – review & editing, writing – original draft, investigation; Giovanni Angrisani: writing – review & editing, writing – original draft, investigation; Dora D'Auria: writing – original draft, investigation; Angela Bosco: conceptualization, writing – review & editing, investigation, visualization, supervision, project administration, funding acquisition; Valeria Cera: conceptualization, writing – review & editing, investigation, visualization, supervision, project administration, funding acquisition; Luigi Fregonese: conceptualization, writing – review & editing, investigation, visualization, supervision, project administration, funding acquisition; Simona Scandurra: supervision.

semantically consistent data extraction, supporting better decision-making in cultural heritage management.

As part of the Great Pompeii Project (GPP), in 2015, the Archaeological Park of Pompeii started the creation of a huge computer archive for the systematic and continuous monitoring of the site: 'The Knowledge Plan' ('Piano della Conoscenza'). The 'Piano' represents an innovative approach to the conservation of cultural heritage, as it provides on one hand the survey of the materials and the state of deterioration of the structures, and on the other hand an articulated system of collection, archival and management of any further essential data for the understanding of the archaeological heritage, monitoring the evolution of its conservation status and evaluating the sustainability and safety of maintenance plans. This heterogeneous information (identification and consistency of materials, surveys, studies, results of analysis, archival documentation, previous interventions, etc.) are collected in a webGIS (for internal staff usage). Then, the documentation is integrated with surveys carried out with laser-scanning and photogrammetric methodologies. However, the structuring of the data is not regulated according to predefined logics since shared and internationally validated rules are lacking. Furthermore, the three-dimensional surveys remain dissociated – clearly identified as of great utility – but lacking a coherent cataloguing and not connected with the rest of the documentary corpus.

2. METHOD

2.1 *The state of the art in BIM and GIS integration*

The BIG-SMAART research initiative is firmly grounded in the existing literature on built-asset digitization and archaeological management fields, in which all partners possess extensive experience. To establish a successful foundation for data integration solutions, a comprehensive and meticulous analysis of the formats and standards available for data exchange in the construction industry, particularly through BIM and GIS technologies, was conducted. To ensure full accessibility (a critical issue in cultural heritage projects where resources are knowingly limited) the focus remained on open format standards (D'ANDREA, FORTE 2020; DIARA 2020): IFC (BUILDINGSMART 2024) and CityGML (OPEN GEOSPATIAL CONSORTIUM INC. 2021) are the dominant standards in their respective fields of building and geospatial data exchange (TAN *et al.* 2023). The study started from taking into consideration the most widespread technologies available into the domain of archaeological planning and conservation: BIM and GIS. Individually they demonstrated to be effective tools for overall asset management (GARRAMONE *et al.* 2022); their integration – object of many studies (DORE, MURPHY 2012; COLUCCI *et al.* 2020; CLEMEN 2022; PEDÒ *et al.* 2023) in different domains — promises to be even more beneficial. In this study, the semantic correspondence between the two worlds is investigated at the schema level integration – between data schemas – of these globally approved standards. Next sections present an in-depth analysis of both selected schemas.

2.2 *Interoperability exchange open formats: IFC*

The BIM approach has been understood, for several years now, as a methodological protocol with a broad cognitive and application spectrum within the AEC (Architecture Engineering Construction) sector. The need to direct the construction chain towards a process that is as controlled and functional as possible (thanks also to the national and European regulatory and legislative trend aimed at greater production efficiency and social well-being) has led public and private actors to implement and adopt this process as a fundamental requirement for the design and construction of works and artefacts.

From an epistemological point of view, BIM is an object-oriented modelling technique. By oriented objects, or rather object-oriented modeling system, we mean an expression of knowledge in the most complete way: as a geometric model and as alpha-numeric informative content. This system does not work by drawing graphic primitives (line, parallelepiped, prism, etc.), but it works directly with and on the object itself (e.g. wall, door, window, etc.). It is readable by the computational resource and, being oriented, already has within itself the set of data and attributes of which the element is composed (existing artefact) or would contain (new construction) in qualitative and quantitative terms. Integrity of the geometric, constructive and geospatial attributes that are associated with modeling in a BIM environment are guaranteed in their interoperability by buildingSMART, the international non-profit organization that manages the transformation of digital flows in the construction sector.

IFC (Industry Foundation Classes) represents the most used standard for data exchange and interoperability between BIM information platforms (Zadeh *et al.* 2019). Specifically, IFC is expressed in its dual nature of scheme and file format. As a scheme it translates into an organizational logic the identity and semantics of objects according to unique identification codes and functions, the attributes and parameters associated with them, and the relationships between objects themselves, between concepts and actors involved in the information process. Furthermore, it can define and catalogue the physical elements of the models, architectural rather than structural or mechanical-system products, manage abstractions useful for structural, energy analysis, cost calculation, timetables and maintenance.

As a file format, however, IFC is configured as an open, non-proprietary and internationally standardized format currently updated to the ISO

16739-1:2024 version. In IT friendly terms, the IFC file derives from the formulation of the concept of 'schema' according to the parent-child relationship, i.e. a root structure whereby all entities are organized hierarchically.

2.3 *Interoperability exchange open formats: CityGML*

GIS refers to digital systems used for storing, analyzing, and presenting georeferenced data. Historically, GIS systems used to deal with two-dimensional spatial data; nowadays, the latest applications include the possible description of entities in three-dimensional version. The three-dimensional representations available are those general to the digital drafting world: surface, multi-surfaces and solids (volumes). By allowing integrating different spatial data sources, GIS allows information, whether 3D or 2D, to be placed in its correct spatial context, enabling a more complex and detailed interpretation of discoveries, which is the main reason why GIS technology is gaining momentum in digitization archaeological studies (DELL'UNTO, LANDESCHI 2022). Similarly to BIM, the nature of GIS is twofold, and combines a geometric information layer and a semantic information layer; the two domains are then crossed by the relations defined by the selected modelling language (TAN *et al.* 2023).

Therefore GIS systems are also, at their core, information exchange systems. They dialogue exchanging data and files written in different agreed-upon standards and languages. The authority responsible of certifying the approved standards, in this case, is the Open Geospatial Consortium (OGC). Over the years, many formats have been drafted and approved by the Consortium: the specifications for each standard are available (and constantly updated) at the OGC webpage. Out of the extensive list, the most popular format used in academic literature and commercial projects is currently CityGML (City Geography Markup Language), mainly because of its capability in handling 3D data, in combination with BIM, and its extensive semantic definition, more complete compared to the others. The standard is at its Version 3.0 release (OGC, 2021), in September 2021. CityGML representations are classified into 0 to 3 LODs (Level of Details) for the city objects (Fig. 1) Additionally, as in with IFC, CityGML is both a semantic model (specified by a formal data model) and an exchange format for virtual 3D environments (KOLBE 2009).

Before version 3.0, geometries depended strictly on the semantics (e.g. openings were represented only in the more detailed classes); afterwards, every concept became representable in multiple and LODs. However, a fundamental difference characterizes the representation of city objects in GML3 compared to IFC: as shown in Fig. 1, in the standard, architectural elements are deconstructed in surfaces, contrary to solids. This is a problem for the archeological needs of the excavation sites, where the experts (to the project) specify the need for a class 'wall' in addition to the 'wall cladding'.

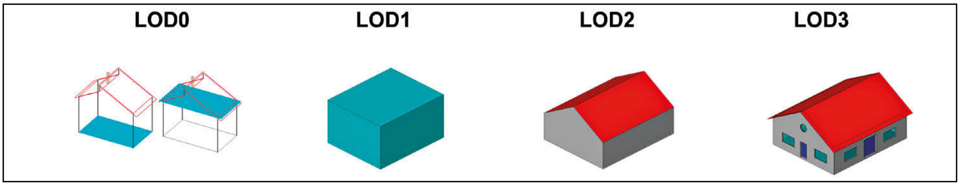


Fig. 1 – LODs in cityGML, reprised from (OGC 2021).

2.4 *The integration*

CityGML is built on XML language, while IFC is based on the STEP one. This fundamental difference entails a difficulty in mapping between them: data from BIM and GIS cannot be simply mapped 1:1 to each other because of the different domains (Schilling, Clemen 2022) from which they originate, and the semantic differences explained above. To date, three proven methods have been identified for integrating the BIM or GIS native datasets (Tan *et al.* 2023); respectively, the data can be mapped from BIM to GIS environment (in terms of standards, from IFC to GML), from GIS to BIM (GML to IFC), or that the two initial BIM and GIS datasets are both mapped to a third schema. Loss of data and of semantic information is common to all methods.

Recent research demonstrates that the BIM-to-GIS workflow is less problematic (Tan *et al.* 2023), especially if the goal is a highly detailed model. However, before starting with experimenting BIM to GIS mapping solutions, making a hasty choice, capable of influencing downstream the quality, the decision was made to analyse in detail the evident shortcomings of the two standards in comparison to Vesuvian archaeology, to clearly understand their individual semantic capability. The data coming from the 'Piano della Conoscenza' combined with the expertise of researchers involved – produced a taxonomy for Vesuvian architectural and archaeological features available in the area, that was used for comparing the standards applied onto reality. The comparison was performed to get a quantitative appraisal of the semantic completeness obtainable for both schemas; interestingly, although the inadequacy of standard schemas for archaeological artifacts is often stated, such a quantitative analysis on an available large asset is not yet present. More generically, the test wants to help answer the main research question guiding the experiment: how the data schemas for the two solutions are apt for describing Vesuvian architecture.

3. Materials and methods

The case study chosen for process experimentation is the Pompeii Archaeological Park. The work began with the creation of the catalogue of

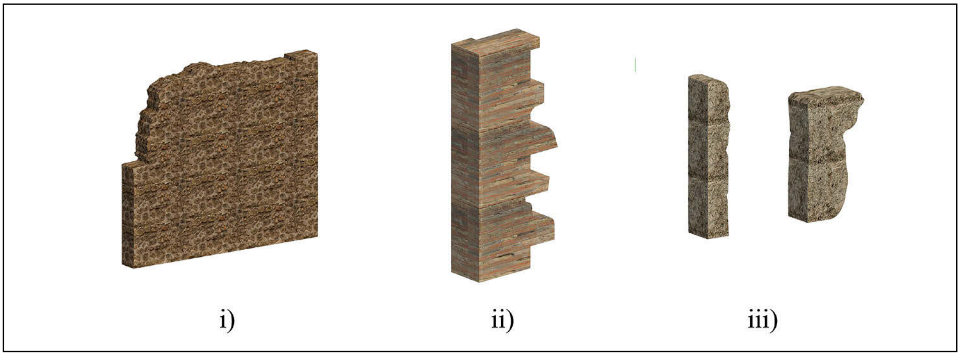


Fig. 2 – Examples of analysed objects: a wall, a quoin and a door opening.

	Object Category	Construction Technique	Materials
i	Wall	'Opera Incerta'	Limestone, Cruma and Lava
ii	Quoin	'Opera Vittata Mista'	Limestone and Brickwork
iii	Door Opening	Blocks	Limestone

Tab. 1 – Three archaeological elements classified by the three criteria: category, construction techniques and materials.

the archaeological building entities, started from the census and listing of building techniques and materials, used in the construction and renovations of the assets. This census was carried out through an analysis conducted on site and on published literature of Republican and high-imperial Roman ages (Ginouvés, Martin 1985, 1992, 1998). The results were incorporated in a list of all the elements that are part of the architectural complex.

Following Pompeii's archaeological evidence, the constituent elements of the archaeological built environment were first subdivided according to three macro categories corresponding to the disciplines, namely structural, architectural and installations. Afterwards, groups of elements sharing the same formal and functional characteristics were distinguished. The definition of the building techniques and materials which can be used in the construction of the element has been considered as a parameter for type identification. Fig. 2 and the associated Tab.1 shows three elements and their classification according to these choices.

According to this classification a wall constructed in 'opera incerta' will differ from a wall in 'opera vittata mista'. At the same time, a wall in 'opera vittata mista' constituted with brickworks and grey tuff, is another record than a wall in 'opera vittata mista' constituted by brickworks and limestone, and so on.

A total of 175 records corresponding to element typologies has been drafted so far. Some extremely specific elements, such as shrines and *sacrarium* were excluded from this step. The definition of the types is based on a reconnaissance of both archaeological evidence and published sources (Carpentiero, D'Auria 2023). After having proceeded with the formulation of the results of this research as a branched structure of archaeological entities of the Roman world, we proceeded to reconstruct the meaningful branches of the IFC schema significant to the highlighted archaeological concepts and analysed their attributes and relationships following the logic described above. Same operation was performed over the CityGML conceptual schema and its various thematic modules.

3.1 *Focus on IFC classes and relations*

It is important to consider that the IFC logic is based on three concepts that represent its structure. They are defined as:

- IfcObjectDefinition: entities, objects.
- IfcRelationship: relationships between entities.
- IfcPropertyDefinition: entity properties.

IfcObjectDefinition, in turn, branches into other subcategories: IfcActor (actors active in the project), IfcControl (time control), IfcGroup (groups of objects), IfcProcess (processes and activities), IfcResource (use of limited resources) and IfcProduct (presence of construction elements in space). It is IfcProduct itself that represents the logical set of concepts such as spatial location and the definition of physical element valid for all existing entities: walls, floors, pillars, doors, windows, etc. From the definition of IfcProduct, therefore physical element, we proceeded to identify a translation from archaeological entities to IFC entities from the definitions of buildingSMART, attributing the parameters of construction technique and materials, and trying to keep intact the relationship data between the objects. Regarding the connections between the parts, has been considered the abstract relationship IfcRelationship, and, in particular, the sub-relationship IfcRelConnect, i.e. a connectivity relationship that links entities to each other based on some criteria: e.g. a window on a wall. Regarding materials, however, it has been considered the concept of IfcPropertyDefinition, a generalization of all the properties constituting a given object. This concept is divided into others subordinate to it, of which IfcPropertySet represents the main information content. From a series of cascading elements, we arrive at the definition of IfcMaterial, that is, the concept that expresses the material consistency associated with an IfcTypeObject through the abstract relationship IfcRelAssociateMaterial.

In our experiment, the association of semantic relationships relies on the concept of Family, the concept of Type, and a library of externally loadable

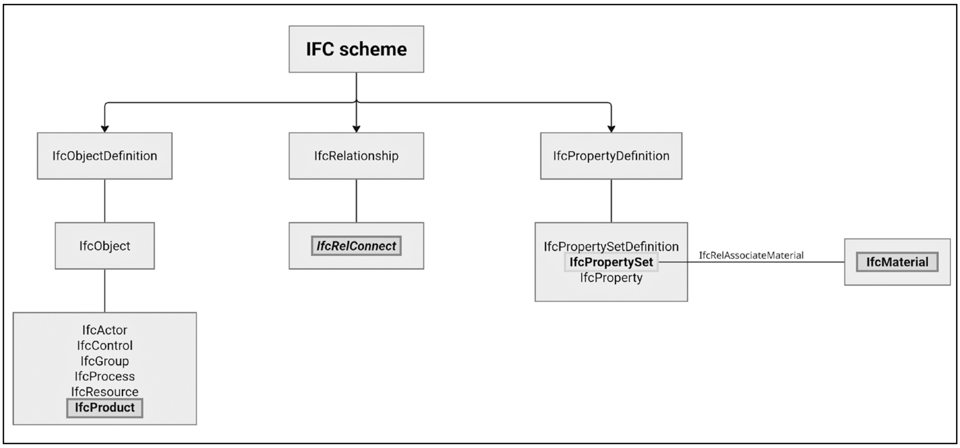


Fig. 3 – IFC synthetic scheme tree diagram.

materials with graphic and physico-chemical properties. In the synthetic IFC hierarchical tree in Fig. 3, the inheritance and connection of most important elements and properties is shown, through the aforementioned relationships, showing objects that are represented and broken down into vertically developing propositions.

The larger mapping extract in Fig. 4 represents the hierarchy of the 'wall' entity starting from the relative nomenclature IfcWall, deriving like all the entities from the root node. The sub-entity IfcWallType was associated with the 'opera vittata mista' construction technique, which was in turn broken down into the material sub-entities of brickwork and limestone. The abstract connectivity relationship IfcRelAssociateMaterial links the IfcPropertySet property compartment to the materials, while the IfcRel-Connect connection allows the connection of the Wall to another element such as IfcDoor.

Since a wall in 'opera vittata mista' (Fig. 4) presents a compound mixture of materials (as it is the case for many of the wall 'operas' of Roman architecture) not subdivided in section layers, in our example, the material definition has to go through another entity, the 'ifcMaterialConstituentSet', which collects both of the components of the opera, 'ifcMaterialConstituents': brickworks and limestone. This passage increases the complexity of the model: not all BIM authoring software can export IFC at this level of detail, therefore, some editing of data with appropriate capacities has to be utilized to manage the IFC exported file. However, the compound mixtures are essential to Roman architecture and have to be represented as such, exploiting the right IFC entity.

3.2 *Focus on CityGML classes and relations*

Compared to IFC, CityGML surely is less complex in terms of hierarchies but is more stratified, with a number of interconnecting thematic modules that range from the most generic item of a city model (the very abstract 'AnyFeature' in the Fig. 5 to elements like Door or Window in the

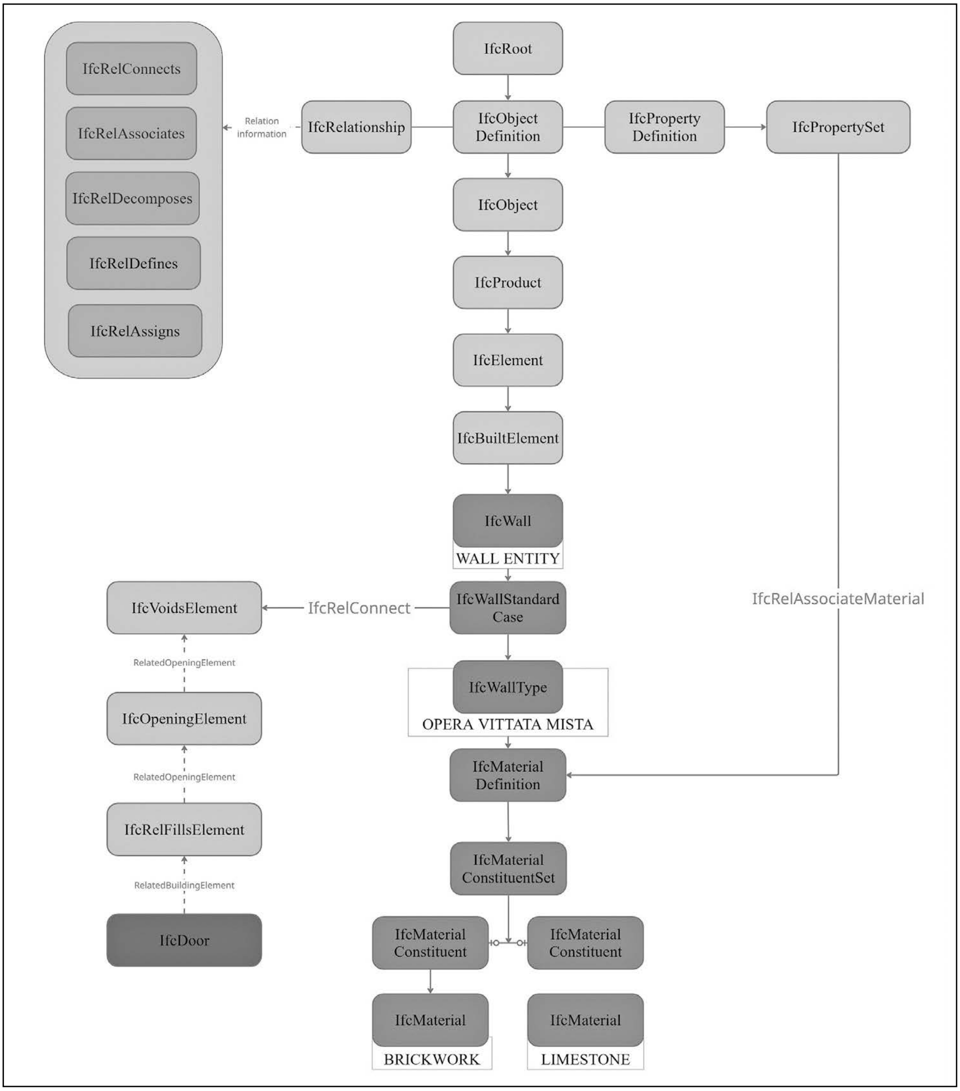


Fig. 4 – IFC mapping extract: 'wall' entity ('opera vittata mista') in relation with the 'door' entity.

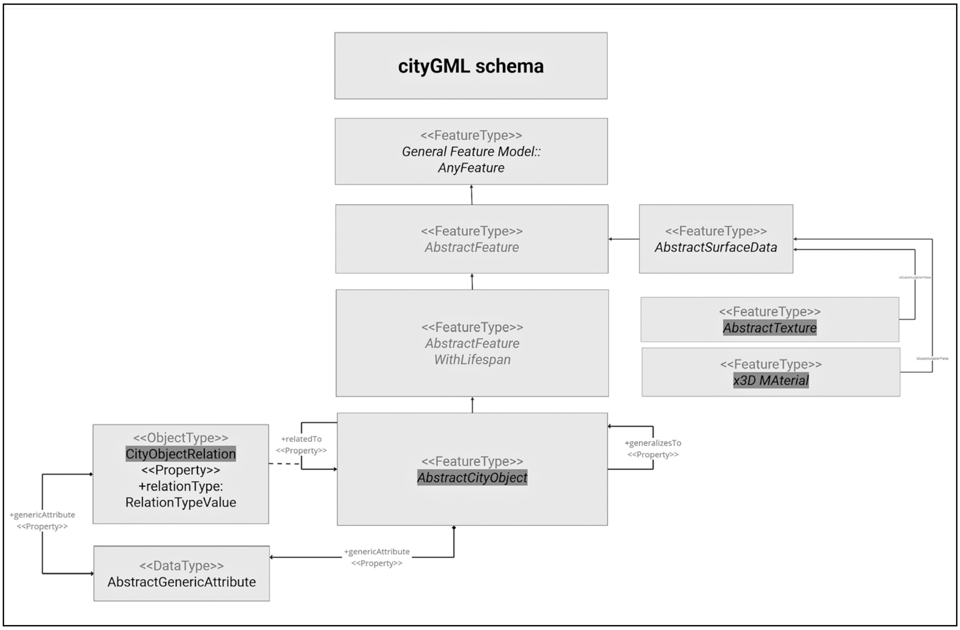


Fig. 5 – CityGML synthetic scheme tree diagram.

lowest levels. Relationships representation is also less articulate: as shown in the schema, the only option available is the CityObjectRelation connected to the AbstractCityObject Feature, upstream of all the more tangible concepts of built environment (walls, door, windows, tunnels) that follow under. To further specify the type of relation, a RelationTypeValue, chosen by the drafter through a previously prepared codelist (more about codelists is explained in the paragraphs to follow), can be eventually selected.

Relationships like those between an object and material ('X3D Material') are more visualization-focused in CityGML, inherited from upstream definitions of AbstractCityObject. It is also notable that information about materials and textures are connected to the visualization and apperance of the model and there is no possibility of connecting more than one material to a single element. A possible roundabout to this problem (using what already available in the schema) is the use of custom-made metadata in the form of 'AbstractGenericAttributes', created on purpose. A wall Entity in cityGML is natively a two-dimensional surface object, and elements such as building doors and windows, also two-dimensional void elements related to the initial surface, lacking the literal depth needed for describing archaeological 3D entities. Using a generic wall as an example, we therefore have a full diagram of

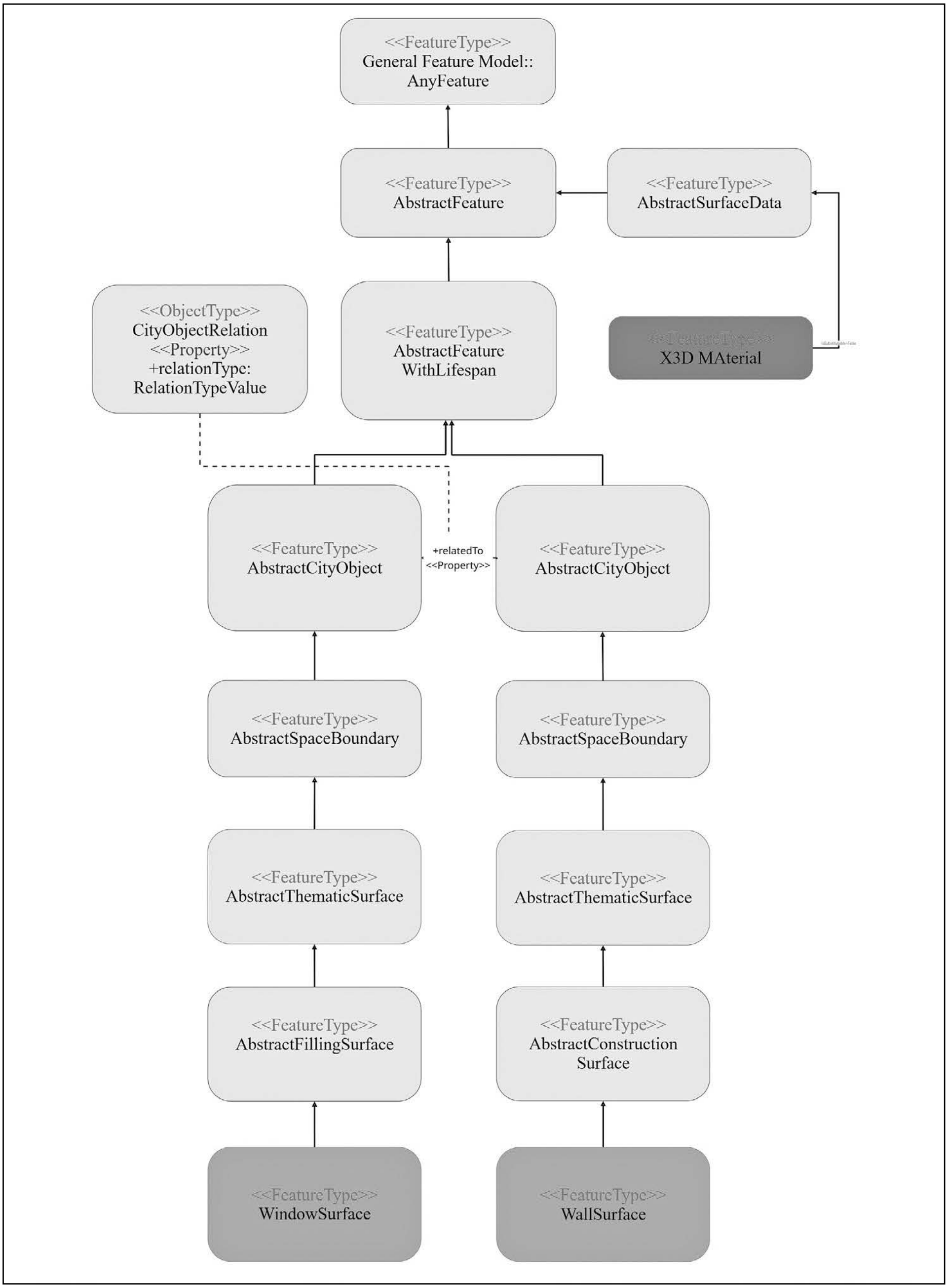
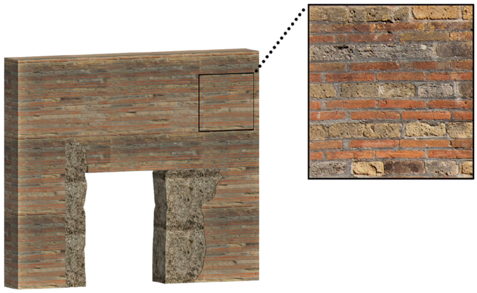


Fig. 6 – CityGML extract, example of a wall and the connected window surface.

the object (WallSurface) and a related window, as in Fig. 6, and the Material parameters upstream.

3.3 *Mapping BIM and GIS classes*

At the core of this experiment is the search for valid semantic classes and concepts -the main ingredient of a representation model – within the already published standards – for Vesuvian architecture. For instance, the 'wall' entity in archaeology maps to IfcWall in IFC (Fig. 7), with construction technique attributes defined by ifcWallType and material attributes linked via ifcRelAssociateMaterial. Meanwhile, in CityGML, the 'wall' concepts exist only as a surface entity ('WallSurface' and 'InteriorWallSurface'), posing semantic challenges as it lacks a solid 'volumetric' definition. The focus of the analysis were classes definitions since, as described before, the attributes and relations strictly depend on them, influencing the entire representation model. The analysis proceeded with the search for the possibility of creating types and variations of the main class definition ('types'), and additionally the possibility of describing the material associated ('material'). 'Class', 'type' and 'materials' therefore compose the three topics of the mapping effort between the archaeological specifications and the published standards as they are (an example in Tab. 2).



```
IFC Representation:
#100=IFCWALL('06cpd6TnX4xRcPyNdYDDTB',#18,'Basic Wall: OperaVittataMista_1015:156269',$,'Basic Wall:
OperaVittataMista_1015',#19494,#21486,'156269');
#101=IFCWALLTYPE('06cpd6TnX4xRcPyNdYDDSe',#18,'Basic Wall: OperaVittataMista_1015',$,$,$,$,'156174',$,.STANDARD.);
#102=IFCRELDEFINESBYTYPE('1$fTJNx01EobeKnnW34EoZ',#18,$,$,(#100),#101);
#103=IFCMATERIAL('Brickworks',$,'Brickworks component');
#104=IFCMATERIAL('Limestone',$,'Limestone component');
#105=IFCMATERIALCONSTITUENT(#103,'Brickworks','Brickworks in opera');
#106=IFCMATERIALCONSTITUENT(#104,'Limestone','Limestone in opera');
#107=IFCMATERIALCONSTITUENTSET((#105,#106),'Opera Mista');
#110=IFCRELASSOCIATESMATERIAL('1MatGUID123456789012',#18,$,$,(#100),#107)
```

Fig. 7 – Wall representation in IFC.

Object Category	Construction Technique	Materials
Wall in	'Opera Vittata Mista'	Limestone and Brickwork
ifcWall	ifcWallType	ifcMaterialConstituentSet

Tab. 2 – Correspondence between the classified element and IFC selected entities.

3.4 *The class correspondence matrix*

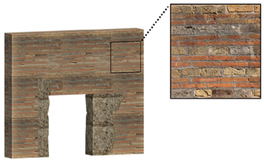
To render the study as quantitative as possible, the semantic mappings were given some values: a perfect semantic correspondence (from archaeological evidence to standard) is 100%. To determine the shortcomings, a correspondence matrix was developed to measure alignment across archaeological, IFC, and CityGML semantic trees. This matrix prioritizes a 'class' definition up to 50% of the matching score (for a full match), a 'type' definition up to 25%, and a 'material' specification for the class up to 25%. Full alignment (100%) is rare, with varying degrees of correspondence; for instance, the IFC wall entity aligns well, while CityGML provides low compatibility.

4. Discussion and results

The discussion now follows with the description of the most relevant discoveries emerged during the comparison of the IFC 4.3 ADD2 data schema and the CityGML 3.0 Conceptual Model Standard against the archaeological entities list developed in the preliminary phases. As expected, walls and wall types make up most of the archaeological site of Pompeii, and solving their correspondences would solve many semantic issues. The numerous wall classes are distinguished by, as stated above, their technology and materials.

Following these criteria there happen to form fifteen wall classes in the archaeological entities list. Against the IFC schema, each one corresponds to the 'IfcWall' Class and can be declined in its own 'IfcWallType'. Then, the 'IfcMaterial' is used to specify the material (or materials) involved in the wall class composition. The correspondence achieved is 100%. CityGML 3.0 is less easy to map: a first semantic issue is that in the data schema the wall concept is not present, favouring the WallSurface and InteriorWallSurface concepts instead; these last two concepts, however fit better, in comparison, to the archaeological classes 'wall cladding decoration' and 'wall cladding preparation', thus were discarded for the solid wall.

The closest representation of the wall, in terms of the whole element in the approved schema, is consequentially the cityGML class BuildingConstructiveElement above, which is evidently vague in its semantic description. However, the CityGML standard is more flexible than the IFC one in the possibility of personalization mechanisms: namely 'codelists', enumerations



```
CityGML Representation:
<bldg:BuildingConstructiveElement gml:id="wall_156269">
   <bldg:class codeSpace="http://example.org/codelists/Class">1000</bldg:class> <!-- specifies a wall -->
   <gen:stringAttribute name="type">
      <gen:value>1015</gen:value> <!-- specifies a wall in opera vittata mista composed of limestone and brickworks -->
   </gen:stringAttribute>
   <lod3Solid>
      <!-- 3D geometry data omitted for brevity -->
   </lod3Solid>
   <app:X3DMaterial>
      <app:name>Brickworks and Limestone</app:name>
   </app:X3DMaterial>
   <core:relatedTo xlink:href="#door_679387"/>
</bldg:BuildingConstructiveElement>

<con:Door gml:id="door_679387">
   <!-- data omitted for brevity -->-->
</con:Door>
```

Fig. 8 – Wall representation in CityGML.

of custom-defined concepts to be applied to approved classes (in this case BuildingConstructiveElement) allowed by the schema specifications. Codelists have three declinations: a fixed list defined in the model definition ('enumeration'), a pattern defining which of all possible strings are valid ('restriction') and an external source, pointed to by a URI, and whose authority must be depended on for the validity of its values. Evidently, the more external a codelist is structured, the less interoperable the model becomes.

To further specify the wall concept, for example, we chose to use, in this case an enumeration codelist (the BuildingConstructiveElementClassValue 'CodeList') specified in the CityGML schema and thus adapt to be used directly. But the value '1000' given through the codelist (already a stretch, in the context of the schema) only specifies the first requirement of the matrix (the element class 'wall') and gives no further possibility to distinguish between 'opera' or construction technique. To achieve this, the mechanism of the 'genericAttribute' has to be implemented, in the shape of a parameter that acts as metadata attached to the model. Although doable, this non-predefined parameter cannot rely on standard, universally accepted values and may lack interoperability with other systems unless they are explicitly defined and documented for specific use cases.

	IFC						
	Class IFC	**%**	**Type**	**%**	**Material**		**Corresp**
WALL	Max value:	50%		25%		25%	100%
Wall OperaIncerta_Limestone	IfcWall	50%	IfcWallType	25%	ifcMaterial	25%	100%
Wall OperaIncerta_LimestoneLavaCruma	IfcWall	50%	IfcWallType	25%	ifcMaterialConstituentSet	25%	100%
Wall OperaQuadrata_Limestone	IfcWall	50%	IfcWallType	25%	ifcMaterial	25%	100%

Tab. 3 – Correspondence values between archaeological walls and IFC classes.

	CityGML						
	class CityGML	**%**	**type**	**%**	**Material**	**%**	**TOT%**
WALL	Max value:	50%		25%		25%	100%
Wall OperaIncerta_Limestone	bldg:BuildingConstructiveElementClass#wall	25%	genericAttribute(type)=1004	10%	X3DMaterial	10%	45%
Wall OperaIncerta_LimestoneLavaCruma	bldg:BuildingConstructiveElementClass#wall	25%	genericAttribute(type)=1003	10%	X3DMaterial	0%	35%
Wall OperaQuadrata_Limestone	bldg:BuildingConstructiveElementClass#wall	25%	genericAttribute(type)=1006	10%	X3DMaterial	10%	45%

Tab. 4 – Correspondence values between archaeological walls and CityGML classes.

Another issue arises now that the wall has become a more generic 'BuildingConstructiveElementClass', the issue of its relationship with the entity for the solid (not bidimensional) Door class (con:Door). At this point the relationship to use has to be the very generic an hierarchically upstream (core:RelatedTo), and the annexed 'xlink' mechanism to refer to other objects is the same GML file. Fig. 8 illustrates this solution.

In conclusion, in contrast to the IFC schema, it is evident that cityGML is, in its original state, less semantically descriptive for the wall concept, but also more customizable. Tabs. 3 and 4 illustrate the mapping process and the method conducted for other elements specified in the archaeological tree.

		CityGML						
	class CityGML	**%**	**type**	**%**	**Material**	**%**	**TOT%**
COLUMN	Max value:	50%		25%		25%	100%
Pillar Operavittatamista_BrickworksLimestoneblocks-Greytuffblocks	**geobim:**Column	50%	genericAttribute=7001	10%	X3DMaterial:	0%	60%

Tab. 5 – Correspondence values between archaeological pillar and the CityGML 'column' class from the GeoBIM ADE.

As cityGML does not allow multiple material association, the value 0% is assigned, in the matrix, to all objects not constituted by a single material.

The process was iterated over all the elements in the Archaeological Semantic Tree, where each class presented similar conundrums and decisions to take. Whilst IFC was used integrally and with no modifications, CityGML was integrated with the ADE 'GeoBIM' (De Laat, Van Berlo 2011), an extension module already approved by the geospatial community, that include BIM concepts to facilitate the mapping between the two standards. It is important to note that, while recognized and important, the ADE is not aligned to the version 3 of the standard yet. Tab. 5 illustrate an example of class taken from the ADE.

We note that a possible inclusion of the 'wall' concept (as a solid element, instead of a surface) in the GeoBIM ADE would solve the complexity of the codelist mechanism, illustrated above, and should be considered. What emerged from this experience is, in fact, the archaeological necessity of having a separation between the wall intended as a core element and additionally the finishing surfaces. The lack of clearly defined building installations classes of cityGML (Zadeh *et al.* 2019), despite its other advantages, made pointless its comparison to IFC: in this field, the buildingSMART standard is definitely more adapt.

5. Conclusions

The analysis ended with the percentage values illustrated in Fig. 9 through histograms: each column represents a class and its closeness to the full correspondence to the Archaeological Semantic Tree. They detract from the semantic validity of the concepts over-simplifications, concepts that do not perfectly correspond to archaeology, overly general descriptions, opinable semantic choices (e.g. in the analysis, a threshold is considered first and foremost a door entity). The personalization of CityGML expand its use but

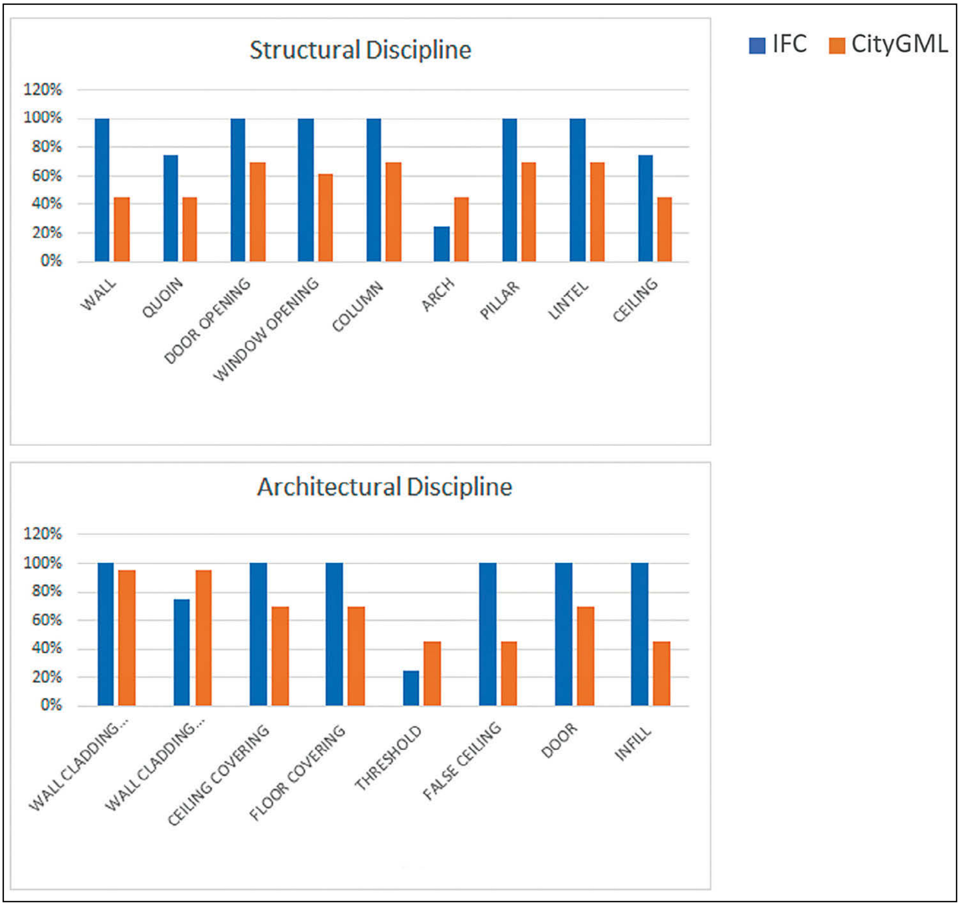


Fig. 9 – Final results of the analysis.

also hinder its overall comprehension and possibly complicate query mechanisms. The graph therefore shows that however rigid and complex, IFC better describes the features of Vesuvian republican Roman architecture.

6. Current and future works

The current findings highlight the limitations of IFC and CityGML in capturing the material-structural nuances of archaeological sites, necessitating further refinement or possible new standards for seamless integration. Although what was discovered in the experimental phases favours the instrumental value of IFC over cityGML; it is also true that CityGML offers more personalization mechanism which could significantly improve the semantic correspondences. In future developments, this possibility should surely be investigated through the development of a ADE, similar to the GeoBIM one, specific to Vesuvian Architecture, as done in (Iñaki Prieto *et al.* 2012; Costamagna, Spanò 2013). The ADE would solve the codelist verbose mechanism by creating all the specific classes necessary to the archaeological practice on these assets and the consequent related attributes. Lastly, the mapping analysis must be carried onto other knowledge structures and taxonomies typical of the cultural heritage sector.

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ABSTRACT

The Pompeii Archaeological Park is an exceptional example of archaeology where architectural features have been almost totally preserved, in the context of an archaeological excavation. Because of this unique site, a digital management tool constructed upon the planned conservation needs, requires both the features of a BIM (Building Information Modelling) and a GIS (Geographic Information System). This article presents the first steps taken towards the design of such system, where the latest research in the integration of the two technological domains takes into consideration the requirements from the archeologists that will use the system. In particular, semantic mappings between entity classes are explained: the data schemas compared are the open format standards for BIM and GIS, namely IFC and CityGML, against a dedicated taxonomy created specifically for this research on the features of Vesuvian architecture.

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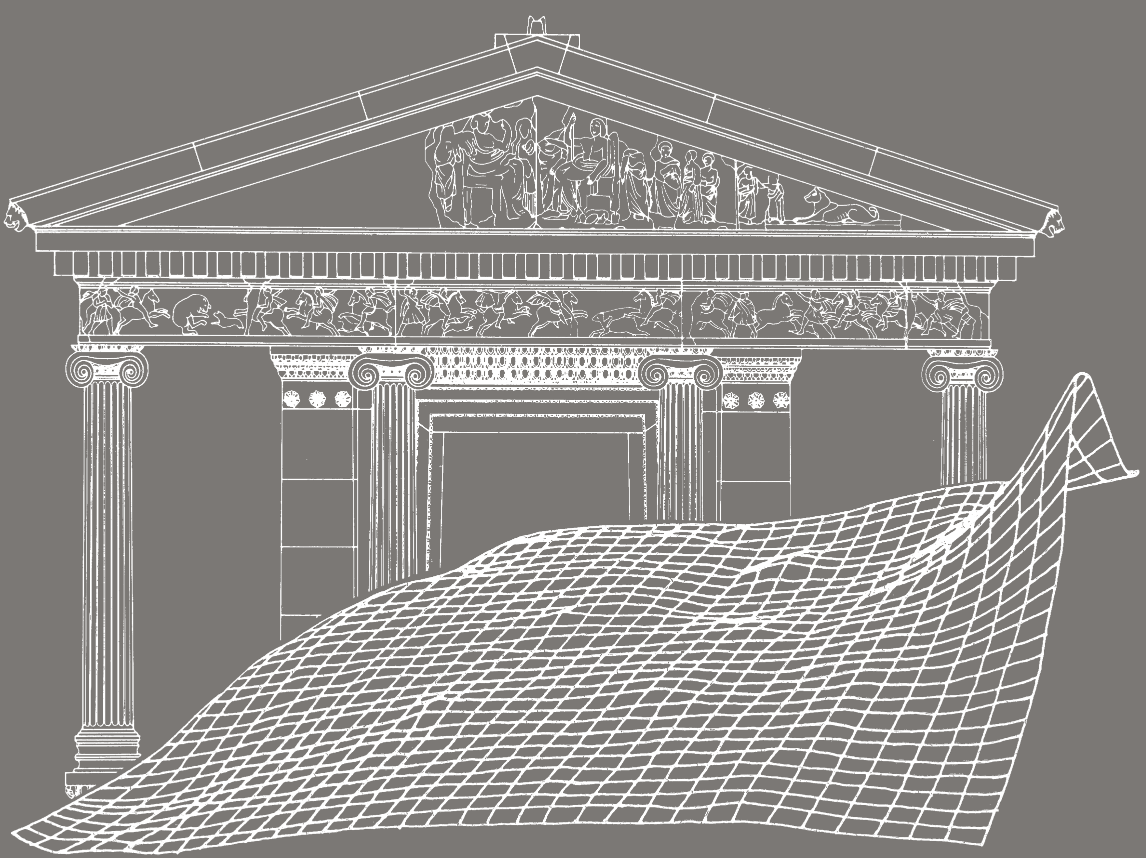

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