A Semantic Web Case Study: Representing the Ephesus Museum Collection Using Erlangen CRM Ontology

Tuğba Özacar(✉), Övünç Öztürk, Lobaba Salloutah, Fulya Yüksel, Baraa Abdülbaki, and Elif Bilici

Department of Computer Engineering, Manisa Celal Bayar University, 45140 Manisa, Turkey
{tugba.ozacar,ovunc.ozturk}@cbu.edu.tr, {lobaba.salloutah,fulya.yuksel,baraa.abdulbaki, elif.bilici}@ogr.cbu.edu.tr

Abstract. Cultural heritage has recently become an important application area for Semantic Web technologies. Semantic Web technologies and ontologies provide a solution for intelligent integration of heterogeneous data about the cultural heritage. The objective of this paper is the construction of an ontology for the cultural heritage related to Selçuk region in Western Turkey. We use a subset of the Erlangen CRM as our ontology schema, then we populate the ontology with 814 objects in the Ephesus Museum. One of the objectives of this work is to integrate the ontology with other projects which use Erlangen CRM as ontology schema. Therefore, we present an integration case study that aggregates content from Ephesus Museum and British Museum.

1 Introduction

The data about the heritages in museums of Turkey is heterogeneous and fragmented. Worse still, a significant part of data is not digitized. This is a major obstacle to accessing and integrating the information. On the other hand, by its nature, cultural heritage is a domain with very dense interrelations within and between different heritages, which in the current situation are impossible to exploit [1]. The difficulty of finding and relating information in this kind of heterogenous content is an obstacle for end-users. Producing the contents is also another challenge to organizations and communities. Portals like Google Arts & Culture try to ease these problems by collecting content of various publishers into a single site [2].

Semantic Web technologies and ontologies provide a solution for intelligent integration of such heterogeneous information. An ontology provides formal, machine readable, and human interpretable representations of a domain knowledge. [3] discusses current shortcomings in the Semantic Web management of

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cultural resources and future research directions. It specifies that the multidisciplinary nature of analytical data in cultural heritage field requires advanced techniques for optimal data integration and knowledge reuse. The merging and integration of this multidimensional information has the potential to uncover new knowledge about artworks. Semantic Web technologies play a crucial role in improving data integration as well as reasoning over dynamically evolving data via fuzzy inference rules. A major application type of Semantic Web in the cultural heritage domain has been semantic portals [4,5]. These portals often aggregate content from different organizations, thus providing cultural organizations with a shared cost-effective publication channel and the possibility of enriching collaboratively the contents of each other's collections [6].

In this work, we define the inventory records of the Ephesus Museum in a computer readable format using Semantic Web technologies and ontologies. The Ephesus Museum, located near the entrance to the Basilica of St. John in Selçuk/Turkey, displays excavations from the ancient city of Ephesus. The main highlights are two statues of the Ephesian Artemis, frescoes and mosaics. As a basis for the ontology schema, we chose the Erlangen CRM [7], which is an OWL implementation of the CIDOC Conceptual Reference Model [8]. The Erlangen CRM is used by various projects and initiatives, including The British Museum Ontology [9], SWAS (Sharing Ancient Wisdoms) Project [10], Synat Open Platform [11] and WissKI Project [12]. Then we populate the ontology with 814 objects exhibited by the Ephesus museum.

There are several similar works in literature. For example [13] applies linked open data methodologies to Greek vases. [1] compiles the knowledge around the cultural heritage related to Cantabria region in Spain. To the extent of our knowledge, this work is the first attempt to use Semantic Web technologies in a Turkish museum.

This work has three objectives: (a) specify the ontology schema which is a subset of the Erlangen CRM (b) Populate the ontology with class and property instances (c) Integrate the ontology with other projects which use Erlangen CRM as ontology schema. Section 2 represents the Erlangen CRM subset that is used in our work. Section 3 represents the individuals in our knowledge base. Section 4 describes how we define the interrelations between heritages in Ephesus Museum and the ones in the British Museum. Finally, Sect. 5 concludes the paper with summary and future directions.

2 The Ontology Schema

An important contribution of Semantic Web technologies in cultural domain is the CIDOC-CRM ontology. It is a formal ontology intended to facilitate the integration, mediation, and interchange of heterogeneous cultural heritage information. The Erlangen CRM/OWL is an OWL-DL 1.0 implementation of the CIDOC Conceptual Reference Model (CIDOC CRM). In this study, we used a subset of the standard Erlangen CRM ontology as our ontology schema. We identified the Erlangen CRM concepts that will be used in the ontology

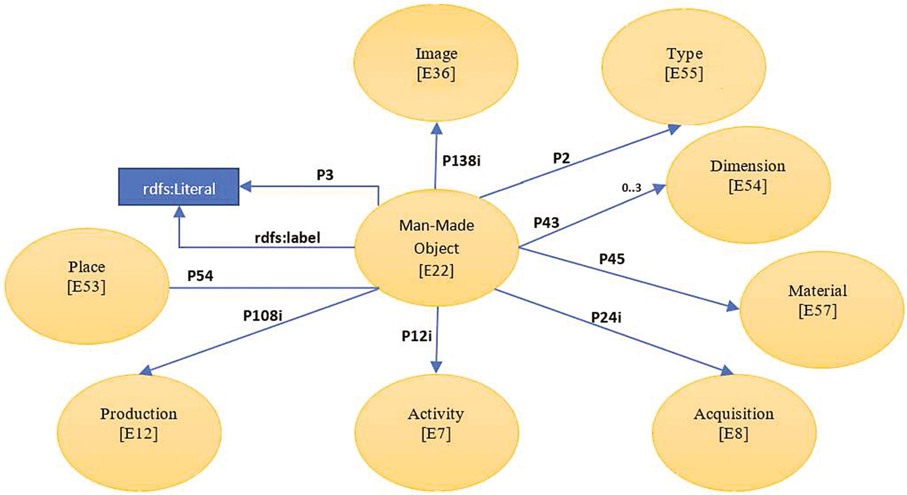

Fig. 1. E22_Man-Made_Object class.

schema according to two factors: (a) the available information of the objects in Ephesus Museum (b) the concepts used in the semantic representation of the British Museum collection. Using these two factors, each object in the museum is defined as an instance of the $E22\_Man-Made\_Object$ in Fig. 1. An instance of $E22\_Man-Made\_Object$ may have the following properties; type, image, material, label, description, dimension, production info, excavation info and acquisition info. The rest of this section presents the definition of each concept in Fig. 1. These definitions are taken from [7].

E22_Man-Made_Object: This class comprises physical objects purposely created by human activity. For example: an inscribed piece of rock or a preserved butterfly are both regarded as instances of $E22\_Man-Made\_Object$.

E38_Image: This class holds the artifacts' images links as they are saved on a local host.

E57_Material: This class holds the materials consisting the artifacts. This class is a specialization of $E55\_Type$ and comprises the concepts of materials. Instances of $E57\_Material$ may denote properties of matter before its use, during its use, and as incorporated in an object.

E55_Type: This class holds the type of the artifact. This class comprises concepts denoted by terms from thesauri and controlled vocabularies used to characterize and classify instances of CRM classes.

P138_has_representation (represents): This property links the artifacts with their images by establishing the relationship between an $E36\_Visual\_Item$ and the entity that it visually represents.

P45_consists_of (is_incorporated_in): This property links the artifacts with their materials. This property identifies the instances of $E57\_Material$ of which an instance of $E18\_Physical\_Thing$ is composed. All physical things consist of physical materials. $P45\_consists\_of$ allows the different materials to be recorded.

P2_has_type (is_type_of): This property links the artifacts with their types. This property allows subtyping of CRM entities through the use of a terminological hierarchy, or thesaurus.

P54_has_current_permanent_location: This property stores the permanent museum location of the object. The range of the property is an instance of the $E53\_Place$ class. This property indicates the E53 Place currently reserved for an object, such as the permanent storage location or a permanent exhibit location.

P3_has_note: This property is a container for all informal descriptions about an object that have not been expressed in terms of CRM constructs. In particular it captures the characterisation of the item itself, its internal structures, appearance etc.

P43_has_dimension: This property records a $E54\_Dimension$ of an $E70\_Thing$ individual. An instance may have 0 to 3 dimensions.

P108i_was_produced_by(P108_has_produced): This property relates an instance of $E24\_Physical\_Man - Made\_Thing$ class to an instance of the $E12\_Production$ class. The instances of the $E12\_Production$ class stores the actor(s), place and time-span information related with the production process.

P12i_was_present_at (P12_occurred_in_the_presence_of): This property relates an instance of the $E77\_Persistent\_Item$ to an instance of the $E5\_Event$ class. In our ontology, we used this property to relate an $E22\_Man - Made\_Object$ to an excavation activity. In other words, this property is used to store the information about the excavation in which the object is found. The excavation information contains the actor(s), place (findspot) and time-span information related with the excavation activity.

P24i_changed_ownership_through(P24_transferred_title_of): This property is inverse of $P24\_transferred\_title\_of$, which identifies the $E18\_Physical\_Thing$ or things involved in an $E8\_Acquisition$. In reality, an acquisition must refer to at least one transferred item. In our ontology we create an instance of $E8\_Acquisition$ class to store the acquisition date of an object in the museum. If there is an actor related with the acquisition (for example a person who donates the object to the museum), this is also stored in the $P14\_carried\_out\_by$ property of the acquisition instance.

Table 1 summarizes some metrics about the ontology schema.

Table 1. Ontology schema metrics.

# Classes		9
# Properties	# ObjectProperties	8
	# DatatypeProperties	2
Depth of Hierarchy		6

It is also important to note that, all concept and individual names in the ontology are also represented in Turkish. The name of the concept/individual in Turkish is stored using the “rdfs:label” attribute as in the following example (highlighted line):

```
<owl:NamedIndividual rdf:about=
        ``http://erlangen-crm.org/160714/Amulet_of_Female_Figure_2''>
   <rdf:type rdf:resource=
        ``http://erlangen-crm.org/160714/E22\_Man-Made_Object''/>
   <Erlangen CRM:P45_consists_of rdf:resource=
        ``http://erlangen-crm.org/160714/Terracotta''/>
   <Erlangen CRM:P2_has_type rdf:resource=
        ``http://erlangen-crm.org/160714/_amulet''/>
   <Erlangen CRM:P8i_witnessed rdf:resource=
        ``http://erlangen-crm.org/160714/6000-2600_BC''/>
   <Erlangen CRM:P1_is_identified_by>
      <owl:NamedIndividual rdf:about=
        ``http://erlangen-crm.org/160714/4625''>
         <rdfs:label xml:lang=``tr''>4625</rdfs:label>
         <rdf:type rdf:resource=
        ``http://erlangen-crm.org/160714/E42_Identifier''/>
      </owl:NamedIndividual>
   </Erlangen CRM:P1_is_identified_by>
   <rdfs:label xml:lang=``tr''>Amulet Kadın Figürü</rdfs:label>
</owl:NamedIndividual>
```

3 Populating the Ontology

Ephesus Museum exhibits 814 objects, including terrace houses findings, sculptures from the fountains, coins, tomb findings, etc. Ephesus Museum Ontology models these objects as instances of $E22\_Man - made\_Object$ class. All of these instances have the following properties filled in the ontology:

- $P138i\_has\_representation$ (image link)
- $P2\_has\_type$ (type of the object which is compatible with types used in British museum ontology; statue, plate, vase, earring, etc.)
- $P45\_consists\_of$ (material of the object such as bone, bronze, glass)
- $P108i\_was\_produced\_by$ links the object to the instances of $E12\_Production$ class. The instances of the $E12\_Production$ class stores the actor(s), place and time-span information related with the production process. The period of $Production$ (such as Hellenistic, Archaic) is an instance of the $E4\_Period$ class and defines the production period of the object.
- $rdfs : label$ (object name in Turkish)

In addition to the five properties described above, some objects may have the following extra properties: height, width, length ($P43\_has\_dimension$), date of arrival to the museum ($P24i\_changed\_ownership\_through$), permanent location in the museum ($P54\_has\_current\_permanent\_location$), findspot ($P12i\_was\_present\_at$) and description ($P3\_has\_note$) of the object.

The most important class in the ontology is $E22\_Man - Made\_Object$ with 814 individuals. If we ignore the extra properties of the objects with inventory information, then each object has five properties: period, type, material, label and image link. Therefore, we have over 4070 (814x5) property instances in the ontology. The other populated classes in the ontology ordered by their importance (by individual count) are *E4_Period* (310), *E55_Type* (112) and *E57_Material* (24). The total number of class individuals in the ontology is 1260. It is important to note that the number of property instances will be increased as we get the inventory records of the objects in the museum.

4 Integrating Ephesus Museum and the British Museum

In this section, we present a web application to introduce an integration case study that aggregates content from Ephesus Museum and British Museum. The web application provides two main functionalities: (a) querying the Ephesus Museum knowledge base (b) finding the most relevant objects in the British Museum with the selected object from the Ephesus Museum.

Figure 2 shows an example query, which returns all marble objects in the museum knowledge base. User can build a query using the period, type and material fields. These constraints are converted to a Gremlin query and the results are listed on the right of the screen. Each result shows the title and the image of a related object.

User can select and view the details of a result (Fig. 3). In this view, the image and the description of the object are shown on the left of the screen. All remaining properties of the object are listed on the middle part of the screen, including title, dimensions, period, material, findspot and permanent location in

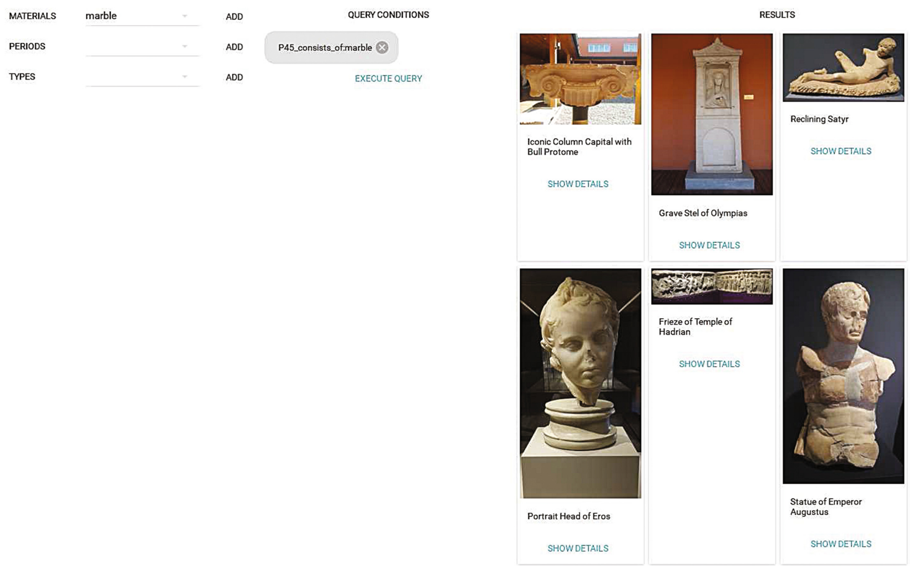

Fig. 2. Querying the Ephesus museum knowledge base.

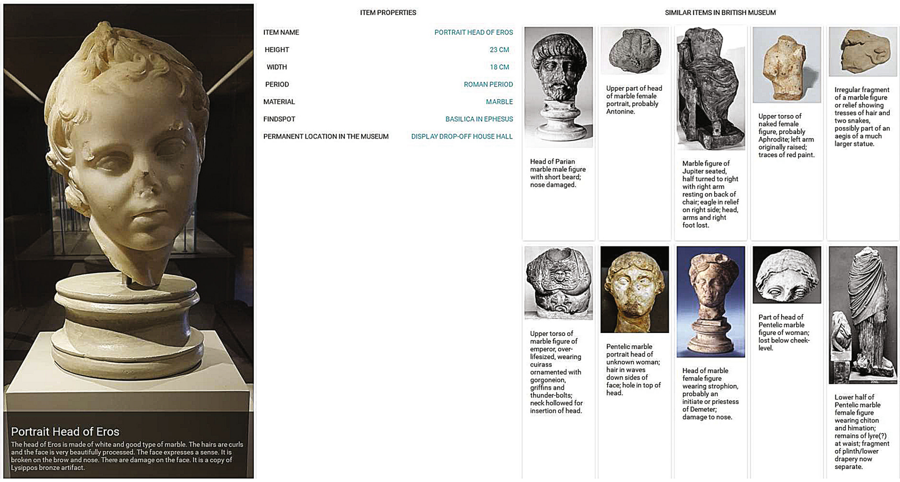

Fig. 3. "Show Details" screen.

the museum. The left and middle parts are the results of Gremlin queries that are sent to Ephesus Museum knowledge base. The right of the screen is used for listing similar objects from the British Museum. The list of these similar objects are obtained using British Museum SPARQL end-point. Then they are ordered from most to least relevant. The order is defined using "Algorithm Relevant_Object_Order", where p is the period, t is the type and m is the material of the object in the Ephesus Museum.

```
ALGORITHM RELEVANT_OBJECT_ORDER (String p, String t, String m)
//returns the objects in the British Museum ordered by the their
//relevance of the current object c.
//The ordered results are returned in  Map<Key, Value>.
// p is the period of c, t is the type of c, m is the material of c.
//check(List,obj) returns 1 if the obj is in the List, 0 otherwise
//merge(L_1, L_2, L_3) merges the three lists into one without repetition
//sort(Map<Key, Value>) sorts the elements in the Map by values
//in descending order

List_1= find the objects having period p in the British Museum
List_2= find the objects having type t in the British Museum
List_3=find the objects having material m in the British Museum
List=merge(List_1, List_2, List_3)
for each object obj in List
    weight_of_obj= check(List_1,obj)*weight_p + check(List_2,obj)*weight_t
                   + check(List_3,obj)*weight_m
    Map.Add<obj,weight_of_obj>
sort(Map<Key, Value>)
return Map
```

The knowledge base of the Ephesus Museum is stored in Cayley [14], which is an open-source graph database. Cayley is developed to be used in applications related with Linked Data and graph-shaped data. User interface is developed using Reactjs library [15]. Communication between Web application and Cayley Graph Database is implemented via Gremlin queries. Gremlin [16,17] is a domain specific language for traversing property graphs. This language has appli-

Fig. 4. Architecture of the web application.

cation in the areas of graph query, analysis, and manipulation. Figure 4 shows the architecture of the Web application.

5 Conclusion and Future Work

This work defines the inventory records of the Ephesus Museum in a computer readable format using Semantic Web technologies and ontologies. It also presents an integration case study that aggregates content from Ephesus Museum and British Museum.

One possible future work is to provide both a SPARQL and a Gremlin endpoint that will be used by other developers to integrate Ephesus Museum collection to their applications. Another possible future work is to increase the property count of the objects in the Ephesus museum by discussing domain experts.

To the extent of our knowledge, this work is the first attempt to use Semantic Web technologies in a Turkish museum. Therefore, we aim to extend this work to other museums in Turkey. The ultimate goal of the work is to create a tool, that enables any museum to easily create and publish its collection using Semantic Web technologies and to integrate its content with other museums having compliant knowledge bases.

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