Towards a Smart Navigation of Cemeteries as Cultural Sites

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Abstract

A cemetery can be thought as a cultural site where each funerary monument represents a point of interest. Similar to other cultural sites, also for cemeteries a strategy should be defined to promote their tourist activity. One of the most recent ways to promote an amenity is based on the publication of Web portals containing information and interactive activities about that amenity. In this paper we propose a Web application for the smart navigation of cemeteries through their points of interests. The Web application can be used in three ways: a) search for detailed information about a specific point of interest, b) navigate an interactive map of the cemetery, c) build one or more tours of the cemetery. The foundation of the Web application is constituted by a knowledge graph, which is used to represent all the entities regarding the cemetery and their relations. Entities of the knowledge graph are represented through the classical strategies employed by the Semantic Web. The use of the knowledge graph permits also the creation of two categories of tours: diachronic and synchronic. The paper discusses also a possible use case of the Web application to the Camposanto Monumentale in Pisa.

keywords

Knowledge Graph, Smart Navigation, Cemetery, Cultural Heritage, Linked Data.

1. Introduction

Over the last years a great effort has been done to give cemeteries the status of cultural and touristic sites. The original hesitancy for tourists to visit cemeteries is fading, and a new tourism category, also known as dark tourism or tombstone tourism, is emerging (Lennon, 2000), due to people with a passion for genealogy and for the history of famous deaths, as well as for art. In addition, in some cases, people are encouraged to use cemeteries as parks, because of the presence of green areas where it is possible to walk, cycle or bring dogs (Isaac, 2014; Evensen 2017). From this perspective, it is important to equip graveyard areas with new

services, available also on the Web, helping common people and tourists to move freely, easily finding the graves of loved ones and famous people, and funerary monuments (Ciolfi, 2013).

Many initiatives have been proposed following this line, such as the Association of Significant Cemeteries in Europe (ASCE)[1], which groups all the most important cemeteries in Europe and tries to promote cemeteries as cultural sites. Existing projects over the Web provide interactive maps, cemetery tours and pages describing entities within the cemetery, such as points of interest, services, persons, events and places. The main limitation of all the existing initiatives consists essentially in two aspects: a) a relation among different entities can be completely missing, i.e. each funerary monument is identified as a single, isolated point, b) a cultural tour, crossing all the most important entities of the cemetery, is not defined.

In this paper, we would like to propose the design of a Web application allowing a smart navigation of cemeteries. The application has an interface that is familiar to the users, as it is inspired by popular mapping applications, and is well suited for mobile devices. A user can search for a person and be guided to a particular grave, or a historical period or a given kind of art, and have a thematic tour specially devised for him/her. The knowledge related to the cemetery is modeled as a graph (Popping, 2003), where each node represents an entity and the edges between two nodes their relation. This way, the information contained in the graph can become very rich and complex. Concepts and tools of the Semantic Web (Berners-Lee, 2001) are used to model data within the graph. In this way, it is easy to retrieve the meaning of every entity and to establish relationships among two or more entities.

The Web Application can be used for three main purposes: a) discover new information about the points of interest contained in the cemetery, b) search for some specific information, e.g. an epitaph on a grave, c) build one or more thematic tours of the cemetery. The Web application provides three main modules to achieve these objectives: a) interactive map, b) search engine, c) diachronic/synchronic tour.

The paper illustrates also a possible scenario of usage of the Web application: the case of the Camposanto Monumentale in Pisa. This cemetery, which is located in the Square of Miracles, was built in different phases, thus constituting a typical case where both diachronic and synchronic tours could be useful.

We present the design of the Wep application for the navigation of cemeteries, even though a complete implementation is not yet available. Nevertheless, we have already implemented a similar application for the navigation of other environments, such as the area of the campus of the National Research council in Pisa[2].

The remainder of the paper is organized as follows: Section 2 describes Related Work, while Section 3 sets the problem. In Section 4 we illustrate our approach and in Section 5 the architecture of the Web application. Section 6 describes the use case and Section 7 gives conclusions and future work.

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[1] http://www.significantcemeteries.org
[2] http://wafi.iit.cnr.it/smartarea/#782

2. Related Work

Many initiatives and projects have been proposed to give cemeteries the status of cultural sites and help citizens appreciate their historical and artistic relevance. Their main objective consists in providing cemeteries with new services that exploit technology to make the exploration of the sites more easy, in order for example to find monuments of artistic relevance or to investigate one's genealogy. In this paper we focus only on services supplied over the Web. Provided services on the Web can be classified in three categories: a) static description, b) interactive map, c) cemetery tour. There is a fourth category, which is out the scope of a cultural site and which consists in equipping a tombstone with a QR code, which contains information about the deceased (Moncur, 2012).

Websites defining a static description of a cemetery provide a HTML page for each point of interest within the cemetery. The page may be more or less detailed and very often it contains also a picture of the point of interest. A famous site of this kind is *Find a Grave*[3], which maintains a large database of cemeteries and graves of the world, with information about the deceased and in some cases with GPS coordinates of the grave. Another category of Web portals for cemeteries provides an interactive map for cemetery navigation. Old portals provided only a static map, which usually could be downloaded as a PDF file. More recent portals, instead, define an interactive Google-Maps-like geographical map, where all the points of interest of the cemetery are placed as markers. In some cases, a click on a marker opens an infobox with detailed information about the related point of interest. An example is the interactive map provided by the Hollywood Cemetery[4]. Finally, the most complex category of Web portals for cemeteries allows users to browse among some pre-defined tours, such as specific tours built for education (Woldemuth, 2016).

Some Web portals about cemeteries exploit Augmented Reality (Azuma, 1997) to add new features to graves or funerary monuments (Matuszka, 2014). The Future Cemetery Project[5] follows this line, aiming at realizing a very ambitious project, where multi-media artists, computer scientists and app creators work together to add value to cemeteries. This project exploits Augmented Reality to represent historical characters telling their stories near their tomb or funerary monument.

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[3] https://www.findagrave.com/
[4] https://goo.gl/WELRrm
[5] http://futurecemetery.org/

3. Problem Setting

A cemetery can be thought as a cultural site, where two main categories of entities are involved: *generic concepts* and *points of interests*. Generic concepts model history, art and other cultural aspects, such as the concept of "sarcophagus" and "Roman Art". Concepts may be connected to each other through different kinds of relationships, such as hyperonymy and hyponymy (Miller 1995). Points of interests represent physical objects located within the cemetery, such as a specific funerary monument or a chapel. Each point of interest is characterized by two kinds of properties: *mandatory* and *optional*. Mandatory properties include the identifier and the geographical coordinates of the point of interest within the cemetery, while optional properties contain specific properties of the point of interest, such as the year of construction and the type of art used to build the point of interest.

A point of interest can be connected to another point of interest by different types of relationships. Without loosing in generality, in this paper, we focus only on two types of relationship: *synchronic* and *diachronic*. A synchronic relationship links two points of interests which refer to the same historical period, such as two graves built in the same year. A diachronic relationship, instead, connects two points of interest which refer to the same subject, such as two funerary monuments or the graves of members of the same family. A specific historical period as well as a specific subject represent two examples of concepts, defined within the cemetery. The problem we propose to solve in this paper consists in defining a mechanism for the smart navigation of cemeteries. This mechanism should permit a user to define personalized tours, both for synchronic and diachronic navigation of points of interest within the cemetery. Since a cemetery is a open-air place, the problem can be formulated as a classical outdoor navigation problem, where smartphones equipped with the Global Positioning System (GPS) can be used.

4. Approach

All the entities and their relationships are organized in a *knowledge graph* (Singhal, 2012), where two types of nodes exist: entities (concepts and points of interest) and property values. Edges between two nodes define a specific link type. For example, the entity "Gherardesca Monument" is connected to the entity "Funerary monument" through the link of type "category". In the following figures, entities are represented through ellipses and properties values through rectangles. This generalization of the concept of node permits a very flexible navigation of the graph thus allowing to solve very complex queries with a minimum effort. For

example, the query "all the points of interest of the 14th Century" needs only to calculate the entities connected to the node "14th Century" (Figure 1).

Such a knowledge graph is behind our Web application.
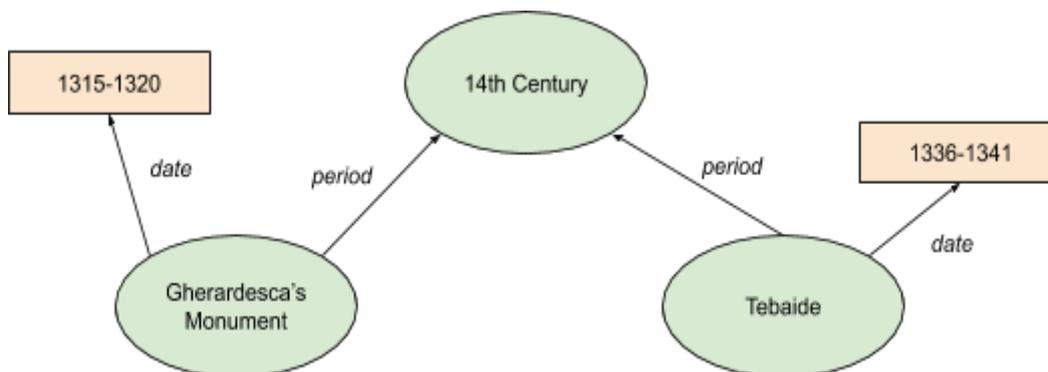
Figure 1: Excerpt of the knowledge graph related to points of interest built during the 14th Century.

4.1 Data Collection

The first step towards the creation of a Web application for cemeteries consists in collecting information about the points of interest of the cemetery. This process is done in two steps: firstly, all the points of interest must be identified and geolocalized through a GPS measurement system. Optionally, a photo of the point of interest could be taken. Secondly, all the relevant properties of every point of interest must be extracted, such as the year of construction as well as the type of monument. This step requires the presence and the competencies of experts, who should classify points of interest according to the historical period and the type of art they belong. Usually, the process of data collection is realized manually and constitutes a bottleneck for the creation of a Web application. However, in some cases, it may happen that the required information about points of interest is already available on the Web, for example in generic portals such as Wikipedia[6] or as an open data archive. In this case, the process of data collection is sped up and consists in retrieving information from those Web sites. Anyway, in this case, the majority of the effort is directed towards data integration and reorganization to populate the knowledge graph.

4.1.1 Open Data about Cemeteries

In 2005 the Open Knowledge Foundation[7] has defined Open Data as data that can be freely used, shared and built by anyone, anywhere, for any purpose. Open data are published mainly by government agencies and public administrations, which collect their data manually from their data portals. Then they aggregate data

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[6] http://wikipedia.org/
[7] http://okfn.org

through a semi-automatic procedure thus producing datasets. A dataset is a collection of information related to a specific category, collected over a specific period of time.

Most of open datasets about cemeteries contains simply the list of cemeteries in a region, with its geographical boundaries, such as the Brussels Open Data Cemeteries[8] and the Belfast Cemeteries[9]. A different approach is followed by the Monumental Archive Project[10], which aims at building a large database of monumental cemeteries, with all details about each grave. At the moment the database contains only cemeteries in Barbados, but anyone can contribute to the project. The whole database can be downloaded as a single CSV file thus permitting the construction of Web applications exploiting it. A similar project is the aforementioned Find A Grave, which contains information about famous people, with their biographies and genealogy. However, the project dataset cannot be downloaded freely, thus the project does not fall under the open data umbrella.

4.1.2 Volunteer Programme

Another possible way to collect information about the points of interest of a cemetery could follow the initiative taken by the Mount Saint Lawrence Cemetery[11], where data about graves were taken by a group of volunteers. A possible work programme to collect data could involve students on a voluntary basis. Such a work programme should require the supervision of at least one teacher, in order to correct some possible mistakes done by students.

The described approach may have multiple benefits. First of all, students would be spurred to learn the art of cemeteries, classify points of interest and attribute them a date. Secondly, students could exploit concepts learned during frontal lessons to compare real objects, plan tours of cemeteries and be involved in various initiatives around the funerary art. From the point of view of the Web application, this work programme should produce a lot of data, which could be included in the dataset.

A different initiative that calls for the work of volunteers is BillionGraves[12]. It aims at collecting a large amount of cemetery data, including images of headstones, their transcriprion, and GPS coordinates. An app created ad-hoc helps the volunteers contribute the database.

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[8] https://opendata.brussels.be/explore/dataset/cemeteries/
[9] https://www.opendatani.gov.uk/dataset/cemeteries
[10] http://monumentalarchiveproject.com/
[11] http://mountsaintlawrence.limerick.ie/
[12] https://billiongraves.com/

4.2 Data Model

Once the information about all the points of interest of the cemetery is available, data can be represented through a data model suitable for the creation of the knowledge graph. In this paper, we model data through the Resource Description Framework (RDF) (Lassila, 1999), a W3C standard used to model Linked Data (Bizer, 2009). Linked Data are a series of best practices to publish data over the Semantic Web, which is the Web of data, in contrast to the standard Web, which is the Web of documents. In RDF everything (in our case all the entities) constitutes a resource. A resource, which is identified by a univocal Uniform Resource Identifier (URI), is characterized by one or more properties and each property has a value. RDF defines a mechanism to represent relationships among resources, properties and values. A relationship is characterized by a triple, composed of a subject, a predicate and an object. Figure 2 models the sentence "Gherardesca's Monument is a Funerary Monument" as a triple.
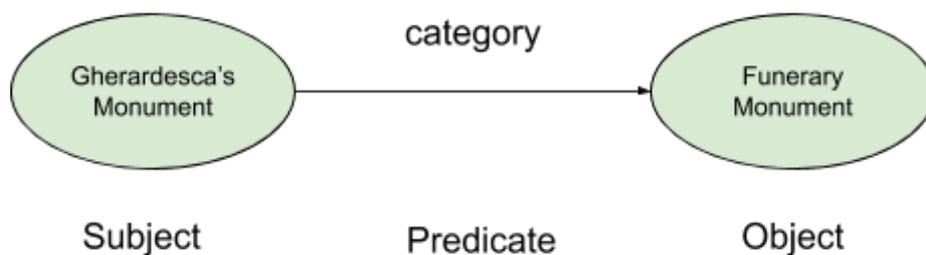
Figure 2: Representation of Gherardesca's Monument as a triple.

When dealing with RDF, resources should be represented through an ontology, which consists in a formal definition of concepts and relationships among resources. Different ontologies have been defined, covering all the domains, such as Tourism, Health, Culture and so on. Anyone can define its own ontology. However, before define a custom ontology, it is a good practice to check whether or not an ontology of the same domain already exists. In this case, such an ontology should be used. Regarding cemeteries, the Graves Ontology (Warren, 2012) could be employed to model points of interest within the cemetery. The following code shows an excerpt of how the Camposanto Monumentale in Pisa could be represented through the Graves Ontology:

```
<graves:Cemetery rdf:about="camposanto-monumentale-pisa">
 <graves:siteName>Camposanto Monumentale</graves:siteName>
 <graves:containsGrave>
  <graves:Sarcophagus rdf:about="sarcofago-degli-sponsali">
   <graves:hasLocation>location</graves:hasLocation>
   <graves:endDate rdf:datatype="Date">
         3rd Century
   </graves:endDate>
  </graves:Sarcophagus>
```

```
  </graves:containsGrave>
</graves:Cemetery>
```

The previous code describes the cemetery as a `graves:Cemetery`. In addition, the code states that the cemetery contains the sarcophagus *Sarcofago degli Sponsali* (specified through the notation `graves:Sarcophagus`), which is located at the location *location* (defined by `graves:hasLocation`). The sarcophagus was built during the 3rd Century.

5 Smart Navigation

Figure 3 illustrates the architecture of the Web application, which can be used both by desktop and mobile devices. There are five modules: the Knowledge Graph, the Search Engine, the Interactive Map, the Diachronic/Synchronic Tour and the User Interface. The Knowledge Graph stores all the entities related to the cemetery and constitutes the main pillar of the application. The Search Engine is the interface to the Knowledge Graph, in the sense that it translates all the queries formulated by the upper layers into requests to navigate the Knowledge Graph. The Interactive Map is a geographical map, which contains all the points of interests of the cemetery. Each point of interest is identified by a marker and a click on the marker opens an infowindow containing detailed information about the point of interest. The Diachronic/Synchronic Tour allows users to build their personalized synchronic and diachronic tours on the interactive map. Both the Interactive Map and Diachronic/Synchronic Tour modules can access to the GPS system, to get the current position of the user and show it on the map. If the GPS is not available, the user can choose a position on the map. Finally, the User Interface defines a user-friendly interface, giving the possibility to the user to choose among the definition of a tour, the simple navigation of the map or the formulation of a specific query.
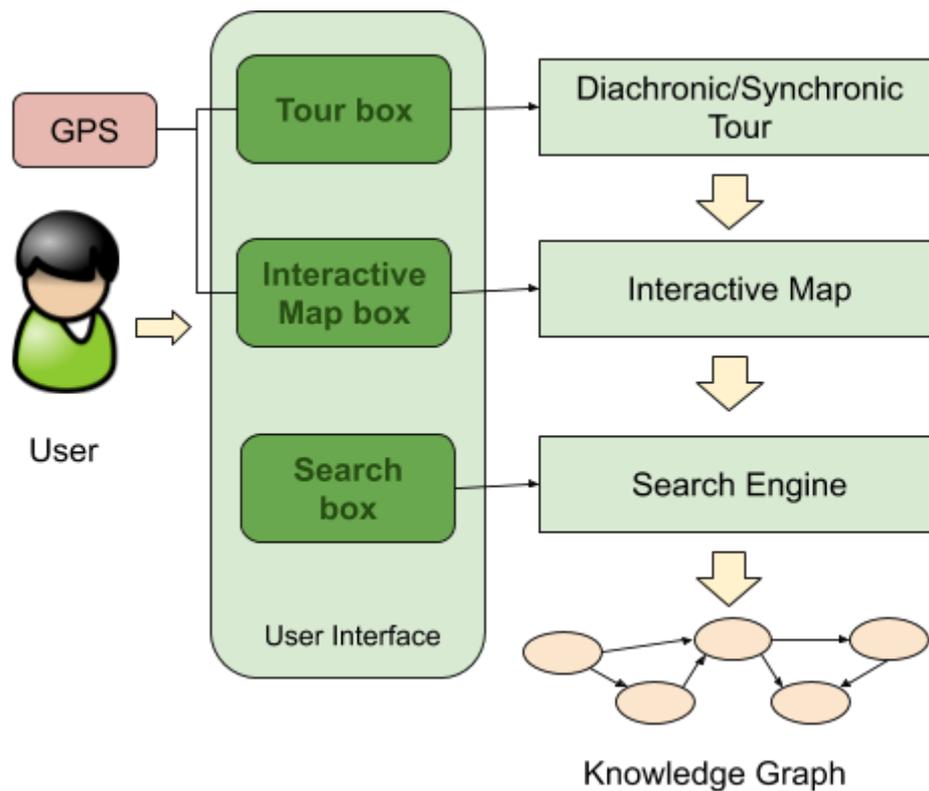
Figure 3: Architecture of the Web Application.

A working prototype of the application[13] is being implemented for the campus of the National Research Council in Pisa, to help employees and guests find people and services in the campus. The area of the entire campus is about 130.000 square meters, 40.000 of which are covered by the buildings, it hosts around 1600 people in 1336 offices, laboratories, and rooms, and includes a hospital, a library, a canteen, a kindergarten, a newsstand, a bike sharing station and other services.

Users can select which floor they want to explore, making all the floors above it invisible. At the beginning the rooftop is selected, so that all the floors, including the rooftop, are shown. If another floor is selected the rooms it contains become visible. The user can also search for a room name or for the name of a person using the search box on the top left corner. The results are shown in a panel below the box. If the user clicks on one of the results, the corresponding room is highlighted, and some details are shown (like for example who works in that room, or which activities are planned in the auditorium, or the opening times of the library). Likewise, the user can click on the placemarks or on the room names on the map to see the details.

Another feature that is currently under development is showing the user the path to be followed get to a specific room, starting from the entrance of the area or from the current user's position.

All the informations used by the application are stored according to the model of knowledge graph discussed before.

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[13] http://wafi.iit.cnr.it/smartarea/#782

5.1 User Interface

We defined a layout composed of three views:

1. *Search box*: the User Interface shows a search bar, which permits a keyword search of points of interest within the knowledge base. A keyword can be for example the name of a monument, the complete name of a person or only their surname, a historical period, an artistic style.

2. *Map box*: this box defines a geographical map of the cemetery, which can be navigated by users. If a user is equipped with GPS, i.e. she is using the application from a mobile device, the map shows also her position on the map. If the cemetery is distributed in different layers, the map permits the user to browse among the different layers, through a series of buttons. The map shows all the points of interest of the cemetery and for each of them, it provides a detailed description.

3. *Tour box*: in this box, the user can define a personalized tour, e.g. a tour containing all the points of interest of 14th Century. Two categories of tours are provided, synchronic and diachronic. In details, the user can choose the subject of the tour, although it must belong to one of the two described categories of tour. Once the tour has been chosen, the application calculates the shortest path, which covers all the points of interest contained in the tour. If the current position of the user is provided, the application considers such position as the starting point of the tour; otherwise the user can select her starting position. If no position is provided, the application assumes that the user is located at the cemetery entrance. The Web application shows the steps of the tour in a Google-Maps-like style: in practice the path to each point of interest of the tour is provided both on the map and as a descriptive text.

5.2 Interactive Map

This part of the system consists in a rich, interactive, HTML5 map of the area, available to users with modern desktop or mobile browsers (Figure 4). No external proprietary services such as Google Maps or similar are used at runtime, which relies only upon a collection of open source Javascript libraries including d3.js[14].

The application leverages a collection of tools and procedures to build and maintain the map. Currently, it consists in a combination of 3D editing software (AutoDesk's AutoCad[15], file format only used as import when a plan of the area has been already traced, and Trimble's SketchUp[16]), and web rendering technologies (the already mentioned Javascript libraries).

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[14] http://d3js.org/
[15] https://www.autodesk.it/products/autocad
[16] https://www.sketchup.com/it

The AutoCad DWG files containing the plans of main buildings are imported into SketchUp, to support an easy 3D editing process. The imported floor plans are then used to create a 3D model of the buildings manually: the most relevant features of the maps are traced and included in the 3D model. The model is georeferenced, in order to match real world coordinates to the coordinates of the 3D representation.

The model is then segmented into a hierarchy of groups. The first level of the hierarchy is used to group the different floors. Walls are in separate groups in order to be able to hide them when the user needs to see inside the building. Rooms or areas of interest, which are interactive elements in the map, are separated from inactive elements at the second level of the group hierarchy. Each area is finally given an identifier at the third level of the hierarchy.

The model is not exported directly in 3D, since it would be too heavy to be loaded at runtime for rendering on mobile devices. Instead it first undergoes a 2,5D projection, that keeps the presentation simple, while giving a 3D effect that is helpful to include relevant details that make the map easier to remember. Then, the layers of the model are exported separately and converted into SVG format. Finally, the SVG is loaded by the application.

Figure 4: An example of the result of the map creation process for the campus of the CNR in Pisa. On the left, the whole building is shown, on the right, the inside of the first floor is visible.

5.3 Search Engine

The Search Engine implements an interface to the Knowledge Graph. The query language used underneath, understandable by the Knowledge Graph, is SPARQL (Prud, 2006), a SQL-like language used to query Linked Data. A predefined list of the more remarkable monuments or people could be the starting point for a user who is not really sure what to search for. The user may also input a string in the searchbox to issue a keyword-based query. An example of a simple query asking for "sarcophagi" could be the following:

```
PREFIX graves <http://rdf.muninn-project.org/ontologies/graves> .
```

```
SELECT ?sarchophagus
WHERE{
     ?sarchophagus rdf:type graves:Sarcophagus.
}
```

Which returns a list of all the sarcofagi that are present in the cemetery, and their properties. Entities and properties are nodes of the graph, and are rendered as clickable links in the graphical interface, so that the user can easily navigate the graph and change/expand her query. Among the properties is, for example, the year of creation -lets' say 14th century- so if the user clicks on that property a new query asking for all the works of the 14th Century is issued:

```
PREFIX graves <http://rdf.muninn-project.org/ontologies/graves> .
SELECT ?work
WHERE{
     ?work graves:endDate "14th Century" .
}
```

Keywords and filters can be combined to ask more complex queries, as for example a list of all the sarcophagi of the 14th Century:

```
PREFIX graves <http://rdf.muninn-project.org/ontologies/graves> .
SELECT ?sarchophagus
WHERE{
     ?sarchophagus rdf:type graves:Sarcophagus;
     graves:endDate "14th Century" .
}
```
This kind of queries are behind the contruction of the tours.

5.4 Diachronic/Synchronic Tours

This module allows users to build personalized tours containing one or more points of interest satisfying some specific criteria. In order to build a tour, the module asks the Search Engine for all entities in the knowledge graph satisfying the constraints of the query concerning the tour. For example, if a user wants to visit all the funerary monuments of a certain century, or the burial sites of people having a given surname, the Search Engine searches in the Knowledge Graph for all the relevant points of interest. Once all the points of interest of the tour have been retrieved, the user can select which ones she wants to visit or choose to visit them all. The module builds a path which covers the selected points. The algorithm used to build the path exploits the geographical coordinates of points of interest to decide the shortest, most convenient path (Floyd, 1962). The tour starts from the current position of the user, if his/her GPS is active, otherwise it starts from a point defined by the user. The next step of the tour is calculated as the point of interest having the less distance from the previous step of the tour. The following excerpt of code represents a possible implementation of how a tour is built. The function receives as input the set of points of interest $P = [p_0, p_1,...,p_n]$, where p_0 is the starting point

of the tour, represented by the user position, a position defined by the user or the cemetery entrance. As output, the function returns the ordered list T of points of interests.

```
function get_tour(P)
    T = []
    push(p_0, T)
    for i in [1, n]:
        p_i = {p_j |  min_j ( |p_j - p_{i-1}| ), j = 1,2,...,i-2,i,...n}
        push(p_i, T)
    return T
```

5.5 Users

Our Web application is envisaged mainly for tourists, although it can be used by any kind of users, such as families of deceased who want to find the tomb of their beloved. Tourists are encouraged to use our Web application to discover new information about a cemetery and to enjoy the art of tombs and funerary monuments.

Three types of tourists can access our Web application easily: *autonomous travelers*, *scholars* and *students*. Autonomous travelers are tourists who plan their trips without a travel agency. Usually they do not have specific knowledge about a place they want to visit and they find information about that place on the Web. For this category of tourists, it is very important to have a Web portal with detailed information about the attraction. Our Web application could be a reference point to explore the cultural site, browsing the map or searching for a specific kind of art.

Scholars may want to visit the area to perform some field research. They have very detailed knowledge about the monuments they want to visit, but they may not know exactly where the monuments are and how to reach them. This category of tourists may search for a specific monument or category of funerary art, and create a personalized tour.

Students represent a hybrid category of the previous two. They have a little knowledge about a place they want to visit and they travel because they want to deepen their knowledge about that place. They could use the application to understand rapidly which are the main points of interest or the most notable deceased and to learn about them. Then they can chose what they want to visit and create a tour.

6. Use Case

In this section we illustrate a possible use case of our Web application with regard to cemeteries. This would demonstrate all the potentialities of our work, but, obviously, our Web application is not limited to it. Instead, it could be applied also to other cemeteries or outdoor cultural sites in general.

6.1 The Camposanto Monumentale

The *Camposanto Monumentale* is the historical cemetery of Pisa (Italy), located in the north part of the Square of Miracles (Caleca, 1996). The Camposanto Monumentale, which constitutes the fifth scene of the square, is the most recent monument located in that square. Its construction started in 1277, but then it was interrupted because of the defeat of Pisa in the Meloria battle. Only in the 14th Century work started again. Its original purpose consisted in collecting all the Roman sarcophagi, which had been disseminated around the Cathedral and had been used as graves for famous people from Pisa. In the 14th Century, the original project was modified completely: the plan was transformed into an approximately rectangular plan with a large central cloister.

The exterior is in plain white marble, with forty three blind arches and two doors. The main access is to the east, and is decorated by a gothic tabernacle over the portal. There are statues of the Virgin and Child and four saints. In the 19th Century the Camposanto became one of the first public European museums.

The cemetery hosts different categories of frescos: biblical stories, stories about death and saints. There are also sarcophagi, mosaic floors and funerary stelae belonging to the Roman art. The Camposanto Monumentale constitutes a good use case for our application, because it contains different categories of entities (frescos, sarcophagi, chapels and other funerary monuments), thus permitting a diachronic navigation. In addition, this cemetery contains entities spanning from different Centuries, thus allowing a synchronic navigation.

6.2 A Smart navigation of the Camposanto Monumentale

Figure 5 shows an excerpt of knowledge graph related to Camposanto Monumentale in Pisa. Two categories of entities are shown: fresco and funerary monument. Also two historical periods are depicted: 14th and 16th Centuries. Thanks to the knowledge graph, two different cultural/educational routes can be extracted: synchronic and diachronic. In the synchronic tour regarding artifacts of the 14th Century, the user is guided

from the Gherardesca Monument to Tebaide, while in the diachronic tour, concerning funerary monuments, the user is encouraged to visit the Gherardesca's Monument and the Giovan Battista Onesti Monument.
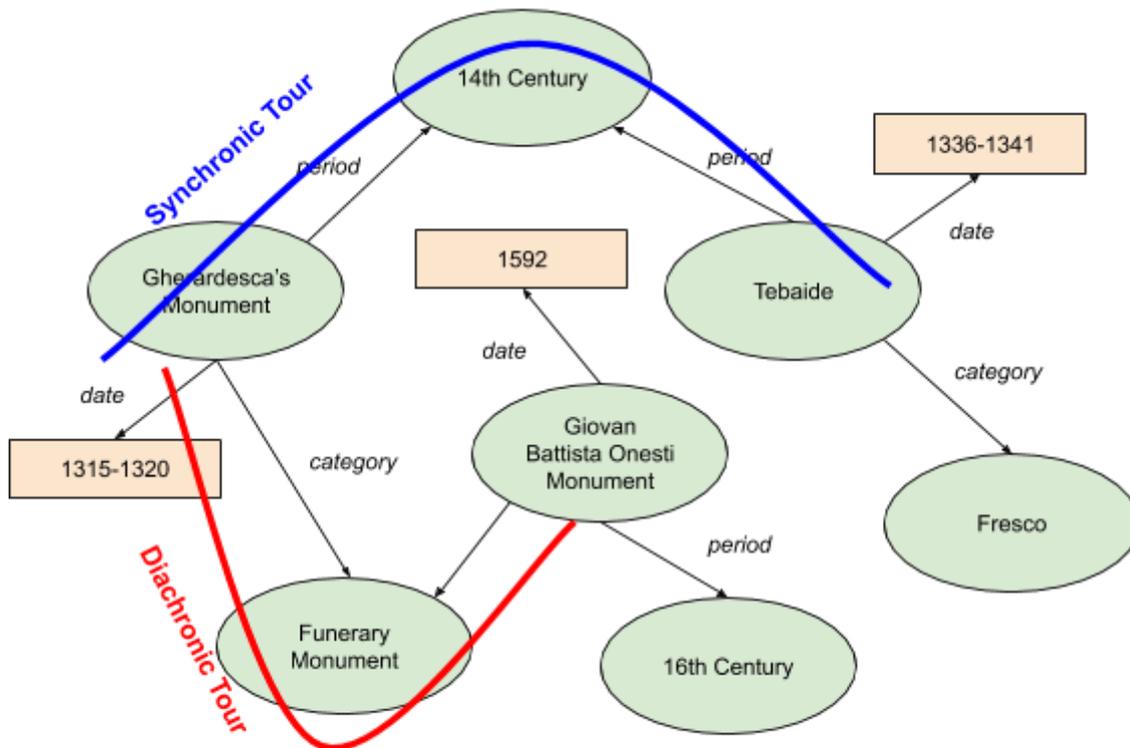
Figure 5: Synchronic and diachronic tours within the Camposanto Monumentale of Pisa.

Figure 6 illustrates a snapshot of a possible Tour box for the diachronic tour with subject "Biblical stories". In the upper left part of the picture, there is a search bar, where the user can type the topic of the tour. As output, the Web application shows the points of interest of the tour, both as text (in the left part) and geolocalized in the map (in the right part). In both cases, points of interest have been ordered and the path from one point to another is shown as a green arrow.
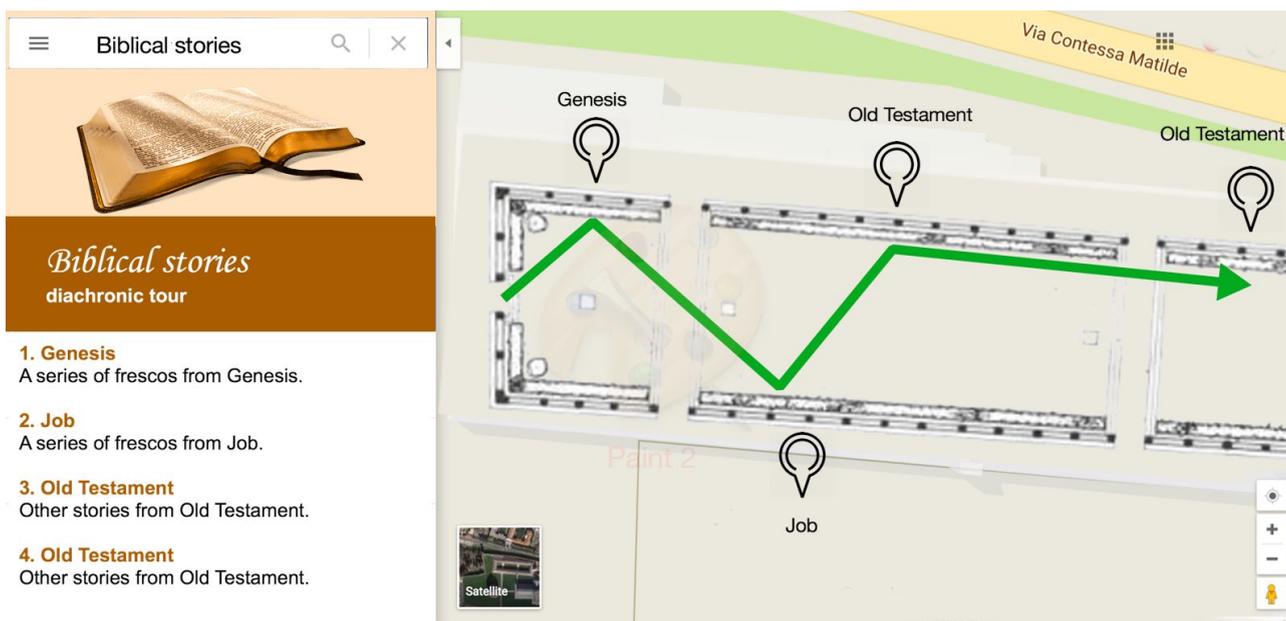
Figure 6: A possible tour box of the Web application.

Figure 7 shows a snapshot of a detailed page about "Job stories". In the left part, there is a textual description of the stories, while in the right part the user can view a snapshot of the selected fresco and can switch to the other frescos.
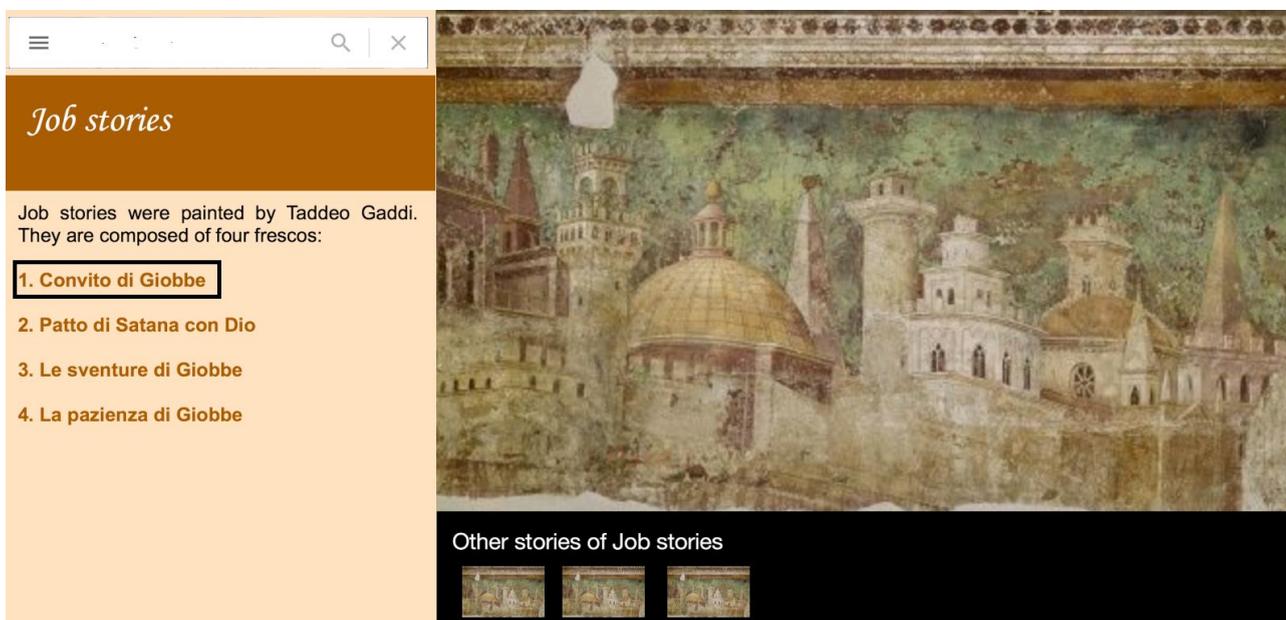

Figure 7: A possible detailed page of the Web application, related to the subject "Job stories".

6.3 A usability test

A possible usability test could be performed by generating a survey, which should guide users to use the features of the Web application. Different usage scenarios should be defined, in order to test features efficiency. The test should have two purposes: understand the Web application enjoyment index and get suggestions to improve the Web application.

The test could be organized in the following tasks:

- [T1] Search for a specific point of interest
- [T2] Explore the interactive map
- [T3] Build a tour
- [T4] General opinion.

Table 1 shows the possible usage scenarios. For each task, a usage scenario is provided and for each scenario, one or more questions are given, specifying also the answer type.

Task	Scenario	Questions	Answer type
T1	Search for a point of interest on the interactive map.	a) how difficult was it to search for a point of interest? b) do you think that the information about the points of interest relevant? c)do you think that the information about the points of interest is well organized?	Range from "very easy" to "very difficult" yes/no/maybe yes/no/maybe
T2	Explore the interactive map	a) how difficult was it to consult the interactive map? b) what do you think about the navigation of the tour	Range from "very easy" to "very difficult" Free answer
T3	Build a tour	a) which tour(s) did you build? b) how difficult was it to build a diachronic tour? c) do you think that the given path is easy to follow?	Free answer Range from "very easy" to "very difficult" yes/no/maybe
T4	General opinion about the Web application	a) what do you think about the Web application layout? b) what do you think about the Web application navigation? d) please give some suggestions to improve the Web application	Range from "very poor to excellent" Range from "very poor to excellent" Free answer

Table 1: A possible usability test.

7. Conclusions and Future Work

In this paper we have described a possible Web application for the smart navigation of cemeteries. The information needed for the Web application is stored in the form of a knowledge graph, to build both synchronic and diachronic tours of cemeteries. The knowledge graph exploits the Semantic Web to model entities thus permitting the extraction of new knowledge from original data. In addition, the Web application provides a very user-friendly interface, which permits users to query the graph, to consult an interactive map and to plan a tour. The Web application is envisaged for three categories of tourists: autonomous tourists, students and scholars. Anyway, it can be exploited by everyone who wants to approach to the world of cemeteries as cultural sites.

At the moment, the Web application is at the stage of design, although it has been already implemented in other domains. Regarding the domain of cemeteries, we have defined the architecture, as well as the basic structure of the knowledge graph. The next step consists in implementing the Web application and test it to the Camposanto Monumentale of Pisa.

We believe our web application has many potentialities in elevating cemeteries to state of cultural sites. Our hope is that we can use it in different environments, not just the Monumental Camposanto of Pisa.

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