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Dipartimento di Ingegneria e Scienza dell'Informazione

– KnowDive Group –

KGE 2022 - Museum Project

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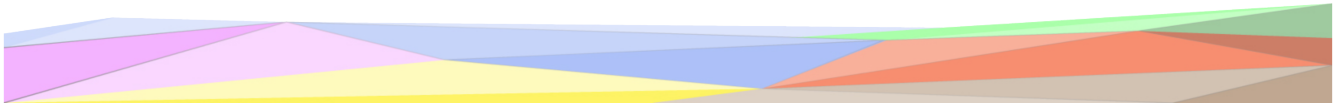

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Revision History:

Revision	Date	Author	Description of Changes
0.1	20.04.2020	Fausto Giunchiglia	Document created

1 Introduction

Reusability is one of the main principles in the Knowledge Graph Engineering (KGE) process defined by iTelos. The KGE project documentation plays an important role in order to enhance the reusabiltiy of the resources handled and produced during the process. A clear description of the resources and the process developed, provides a clear understanding of the KGE project, thus serving such an information to external readers in order to exploit that in new projects.

The current document aims to provide a detailed report of the KGE project developed following the iTelos methodology. The report is structured, to describe:

- Section 2: The project's purpose and the domain of interest and the resources involved (both schema and data resources) in the integration process.
- Section 2: The input resources considered by the KGE project.
- Section 4, 5, 6, 7: The integration process along the different iTelos phases, respectively.
- Section 8: How the result of the KGE process (the KG) can be exploited.
- Section 9: Conclusions and open issues summary.

2 Purpose and Domain of Interest (DoI)

This project considers the integration of heterogeneous data about a museum's visitors' profiles and their visiting behaviours to build a Knowledge Graph(KG).

The specific aim is to create a KG representing museum visitors' profiles and visiting behaviours for different parts of it, in order to guide visitors to the most interesting part of the museum and to help museum owners improve their services. Thus the purpose is to create a service that helps a museum acquire visitors' profiles and preferences for parts of the museum.

The Domain of Interest is inside a museum.

3 Data Sources

The data to satisfy the purpose for building the KG was provided to us by Trient Consulting Group. As for the resources we have 5 main datasets:

- **exhibit**, in which we have id, name, floor-id, type-id, polygon-str, icon-pos-str, parent-id
- **exhibit-type**, where we have id and description
- **floor**, with id, name and scale
- **device-session**, with id, device-id, creation-date, date-start, date-end, position-count, exhibition-count, quiz-count and locale

- **device-session-content**, with id and content

We also look on the Internet for additional resources, and thanks to that we were able to add authors to the exhibits, and a theme to the rooms.

As for knowledge resources, we consulted mainly Schema.org and LIDO. On Schema.org, we found different main resources needed for the project:

- VisualArtwork: describing a work of art that is primarily visual in character.
- Place: entities that have a somewhat fixed, physical extension
- Floor: levels of a building
- Room: a room is a distinguishable space within a structure
- Museum: describing all different properties that a museum can have
- Person: describing all properties our users have
- Thing: the most generic type of item
- Action: an action performed by a direct agent and indirect participants upon an object

.

Then, we examined some others from LIDO; we found some schema referring only to a painting or to an architecture, therefore not really useful for our purpose. After examining all of our knowledge resources, we decided that it would be best to build our own schema basing it on these resources.

4 Purpose Formalization

In order to formalized the purpose, in this section we will present the scenarios, persona, competency questions and the entities identified.

4.1 Scenarios

- **Giovanna** is an art student, being bored on a weekend she has decided to go and visit one museum she has never seen before. She does not have any preference as she loves all this museum has to offer
- **Alex** used to be an engineer but now is on vacation in Venice, one day it was raining and he decided to visit this museum. He is not really fond of art, but wants to see if he will find something interesting as he is in a room full of paintings and wants to know where to start
- **Enrico** is a painter; he needed some inspiration for his new artwork, he went to the museum to see painting of different styles and with different subjects to find other artists to find some ideas

- **Thomas** always had a passion for museums, and now he is the general curator of this one. He has set up the various exhibitions in the floors and rooms of the museum, but would like to understand if there is a more efficient way of doing so and if it can give a better experience to visitors
- **Anna** recently began to appreciate the history of 1700. She found on the internet this museum near where she lives and decided to visit it. She is not too interested in paintings but prefers to see objects related to everyday life.
- **Andrea** has been to this museum many times because he likes the furniture inside some of the rooms. He is a carpenter and want to see only furniture and not all the other exhibits.
- **Micheal** is an English man; this museum has been recommended by the hotel he is staying at. He decided to visit it, but he does not know where to go after finishing to watch one exhibition as he wants to see another one.

4.2 Personas

- Giovanna is a 20-year-old Art student, during the weekends she always try to pick a new museum to visit. She does not have any particular favourite kind of art, as she wants to experience as many styles as she can
- Alex is a 78-year-old retired man, he used to be an engineer therefore not really fond of art. He decided to go and visit the museum to see if he will change his ideas on art.
- Enrico is a 43-year-old painter, when he is all out of inspiration, he usually visits museums in order to look at different styles of painting from different authors to find some ideas to put into his paintings
- Thomas is a 50-year-old museum curator, he wants to always deliver the best exhibitions for the visitors in order for them to come back and still enjoy the experience like it was the first time
- Anna is a 17-year-old highschooler, recently she was gifted a book on the 18th century and has really become fond of the lifestyle during that period
- Andrea is a 32-year-old carpenter, he really like his craft and is curios to see past furniture to see if he can incorporate some elements of what is sees into his pieces to make them more special
- Micheal is a 38-year-old man, he likes Italy so much and tries to visit it as much as he can. He does not read any guide books and usually asks locals for indications and suggestion for what he can visit.

4.3 Competency Questions (CQs)

From the scenarios and the persona depicted before we have create some competency questions that will help with the construction of the KG and with the Entities identification

Person	Question
Giovanna	What exhibit can she see in this floor?
Alex	What is inside this room?
Alex	Where can he find something totally different?
Enrico	Where can he find a room with lots of paintings?
Enrico	Where can he find a painting from this author?
Enrico	What authors are in this museum?
Thomas	What is the most visited room in the museum?
Thomas	What is the most visited exhibit in the museum?
Thomas	What is the least visited room in the museum?
Thomas	What is the least visited exhibit in the museum?
Thomas	What are the themes of the rooms?
Thomas	How many exhibits are in this museum?
Anna	Where can she find a room with a lifestyle theme?
Anna	Where can she see frescoed ceiling?
Andrea	Which furniture is in this museum?
Andrea	On which floor can he find the furniture?
Andrea	In which room can he see the furniture pieces?
Micheal	Where can he find the room of [specific theme]?

4.4 Entities identified

Thanks to the competency questions we have identified different types of entities. For common entities we have the floors, rooms, visitors and museum, the core one are the action performed by the visitor (this entity was not derived from the questions but is at the basis of each of them) and exhibit.

Museum, Floor, Room, Visitor are placed in the common category as they are not strictly related to our Purpose but they are needed to support the building of our KG.

In the core resources we can find Action and Exhibit as they are the most important aspects related to our purpose.

5 Inception

5.1 Resources Collection

The resources collection was done by us but by an agency that gave a tablet to 1000 museum visitors, then they later sent us the database of the data collected. As previously stated the dataset we have received 6 main ones:

- **exhibit**, in which we have id, name, floor-id, type-id, polygon-str, icon-pos-str, parent-id
- **exhibit-type**, where we have id and description
- **floor**, with id, name and scale
- **device-session**, with id, device-id, creation-date, date-start, date-end, position-count, exhibition-count, quiz-count and locale
- **device-session-content**, with id and content

- **questions**, where one can find the question asked to the visitor
- **session-content**, where there is the id of the person, the exhibits they are looking at or the more general actions they are doing

5.2 Data Filtering and Cleaning

As the data we received were not formatted for our purpose, we needed to apply some extended formatting and cleaning of our data.

The data was provided in SQL tables, it has been exported and converted into JSON files, one for each table in order to easily modify them with different Python scripts.

Firstly exhibit needed to be formatted. We searched for the authors of arts and created a JSON with the names of the exhibits and the authors, if it was not possible to trace back to the author who created it the string 'unknown' was put instead of the names. It is better to have the type of exhibit in the same dataset, so a script was produced to match the exhibit to the right type. Thanks to the changes made, starting from the original file we have a new file with id, name, floor, type, location, room, and authors.

For the floor, we remove "scale" and added the id of the museum, together with the floor id and its name.

A dataset for the museum was not provided, so a new JSON was created; inside there one can find the name of the museum, the location expressed in latitude and longitude, the theme, and an id.

In the dataset of the exhibits, there were entries that represented an entire room of the museum, and the exhibits that were not rooms had a reference to the exhibit of type room in which they were located. As it made more sense to have a different entity for the structure of the museum (room) with respect to what is inside (exhibit) we decided to split the dataset of the exhibits in two, creating so a new dataset containing only the entries that were of type room. For each room entry, it has been specified theme (inferred by its name), the points of the four corners of the room, and an id.

Data about the visitors weren't provided directly but in form of a series of questionnaires inside the device-session-content dataset, which we split in actions performed and questions answered. From the questions, we extracted the age group, provenience, gender, and the id representing the visitor. With those data we built the visitor dataset, adding the fields name, surname, occupation, and hobbies, which could be useful in certain types of queries, but as we didn't have that type of information we populated every field with the string "unknown".

From the part of "action performed" retrieved from session-content we extracted the list of different type of actions for each user and concatenated them in a single list adding an unique id for each action. The possible type of action for each user where : started watching an exhibit (i.e. listening the the recorded explanation), finished watching an exhibit, change position, which could mean just a change of coordinates or a change of floor. We joined all the information in a single type of action that has an id, x and y coordinates, a reference to a floor, an optional reference to an exhibit and a timestamp.

Figure 1: Example of the ontology created for Visitor

5.3 Resource Knowledge Definition

As previously stated, we have examined different knowledge resources both on Schema.org and LIDO. On LIDO there were schemas that referred mainly to paintings and architectures, therefore not really useful for the purpose; while on Schema.org we found useful schemas for modelling our entities, as it will help us in being more precise.

Specifically, we used:

- Thing > Place > CivicStructure > Museum
- Thing > Place > Accommodation > Room
- Thing > Intangible > FloorPlan
- Thing > CreativeWork > VisualArtwork
- Thing > Person
- Thing > Action

5.4 Resource Formatting

After having clean and filter the data for our purpose and the collection of them from the resources, we have created the ontology for each of the entity. To make it we used to tools, Protégé and Karma.

An example of the use of Protégé to create the ontology for a dataset can be found in the figure below.

The schema we created with this tool was mapped to the dataset with the help of Karma. Below you can find a figure with an example of what was created.

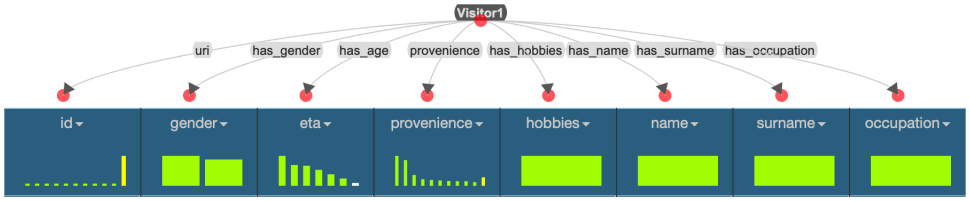


Figure 2: Example of Visitor mapped in Karma

6 Informal Modeling

6.1 ER Model Description

During this phase the ER model model was created, based on the following entities:

- *Common Entities*: Museum, Floor, Room and Visitor
- *Core Entities*: Action and Exhibit

As the purpose for this KG is to profile visitors' visiting behaviours in different part of the museum, we decided to have "Action" as a central entity for this ER model.

6.1.1 Common Entities

Museum

The relationships are:

- SpatialPartOf Everything
- Has Floor

The attributes are:

- location (string)
- name (string)
- theme (string)

Floor

The relationships are:

- Has Rooms

The attributes are:

- name (string)

Room

The relationships are:

- Contains Exhibit

The attributes are:

- theme (string)
- dimension (Points)

Visitor

The relationships are:

- Doing Action

The attributes are:

- name (string)
- surname (string)
- age (string)
- occupation (string)
- hobbies (string)
- gender (string)
- provenience (string)

6.1.2 Core Entities

Exhibit

The attributes are:

- title (string)
- style (string)
- authors (string)
- position (points)
- room (string)
- museum(string)

Actions

The relationships are:

- Involves Exhibit
- In Floor

The attributes are:

- location_x (float)
- location_y (float)
- timestamp (date)
- language (string)

6.2 Teleology building

After explaining specifically the entities that make up our model ER, highlighting both properties and the main attributes we can now go to the description of teleology and how we built it.

Because the spatial context of our KG is the museum, to better define it, we have put in the graph, as a starting point, the ”Contextual Everything”. The museum is a connected with this as it is a spatial part of everything. This connection will help a build a more precise KG, as it is limited to that museum.

The lines inside the ER model provide the connections between the entities. There can actually be more and different relationships than the ones we highlighted in the graph, but this relations are limited to the purpose and the CQs of our project. For example, Action is a more ’central’ entity we decided to base most of the connections around it, as this decision will better satisfy the project’s purpose.

Giving a brief description of the connections starting from Museum one can see that it has Floor and is the spatial part of the Contextual Everything; Floor has Room and Room contains Exhibit. Action involves Exhibit and is done in Floor, Visitor is doing Action.

The different colors of the model are also important, if an entity is in blue it means that it is a common entity, if it is in green it means that it is a core entity. 1

Protégé was used in this phase to create the teleology, the ontologies created in the previous phase have been uploaded onto the tool in order to create the integrated teleology.

7 Formal Modeling

For this phase, we created a new Protégé file to create the ETG. Through the help of Schema.org, as we have already mentioned in the second paragraph, we were able to set our entities with the following relationships:

- Visitor *is-a* Person

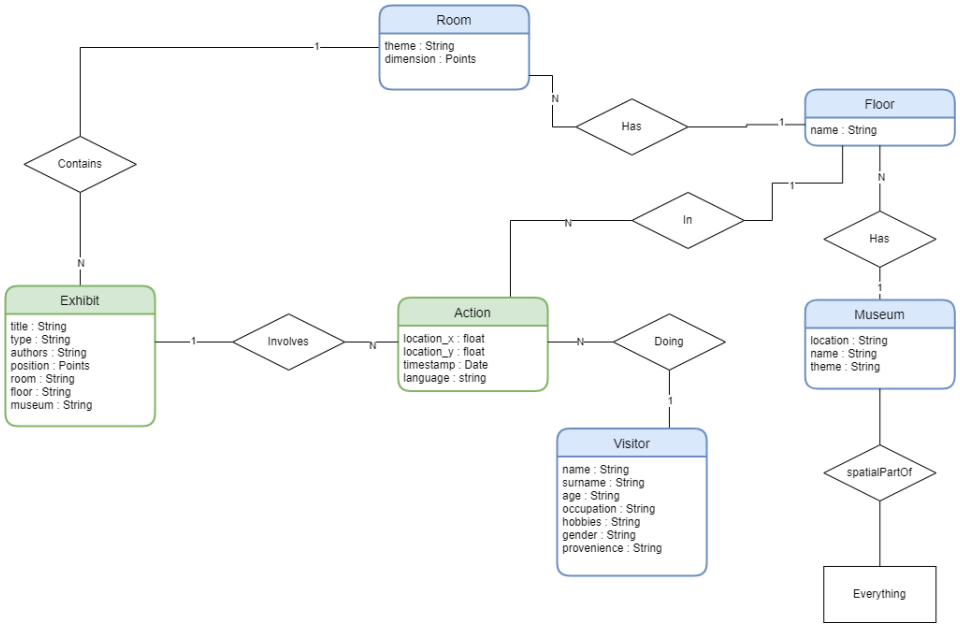
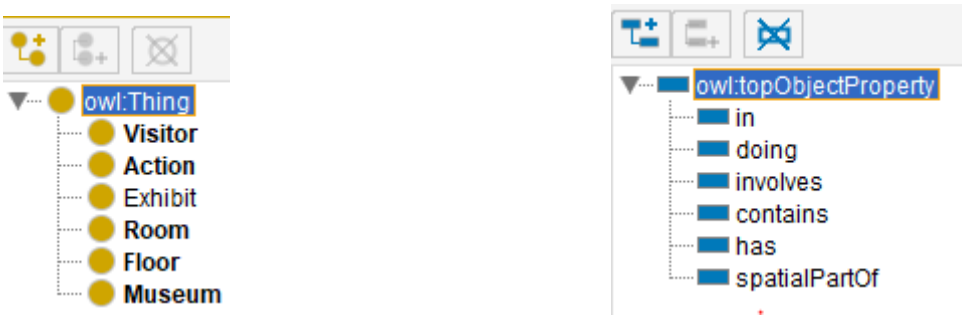


Figure 3: ER Model



(a) Teleology Entities

(b) Teleology Object Properties

Figure 4: Example of Teleology in Protégé

- Floor *is-a* Place
- Museum *is-a* Place
- Room *is-a* Place
- Action *is-a* Thing
- Exhibit *is-a* VisualArtwork

We are aware that the entities presented in our graph are few, but being our purpose very specific to the museum the entities, for example, are not as many as they could be with a purpose linked to the university.

In order to be more precise, we have drawn a graph to better represent the teleontology we have created with Protégé

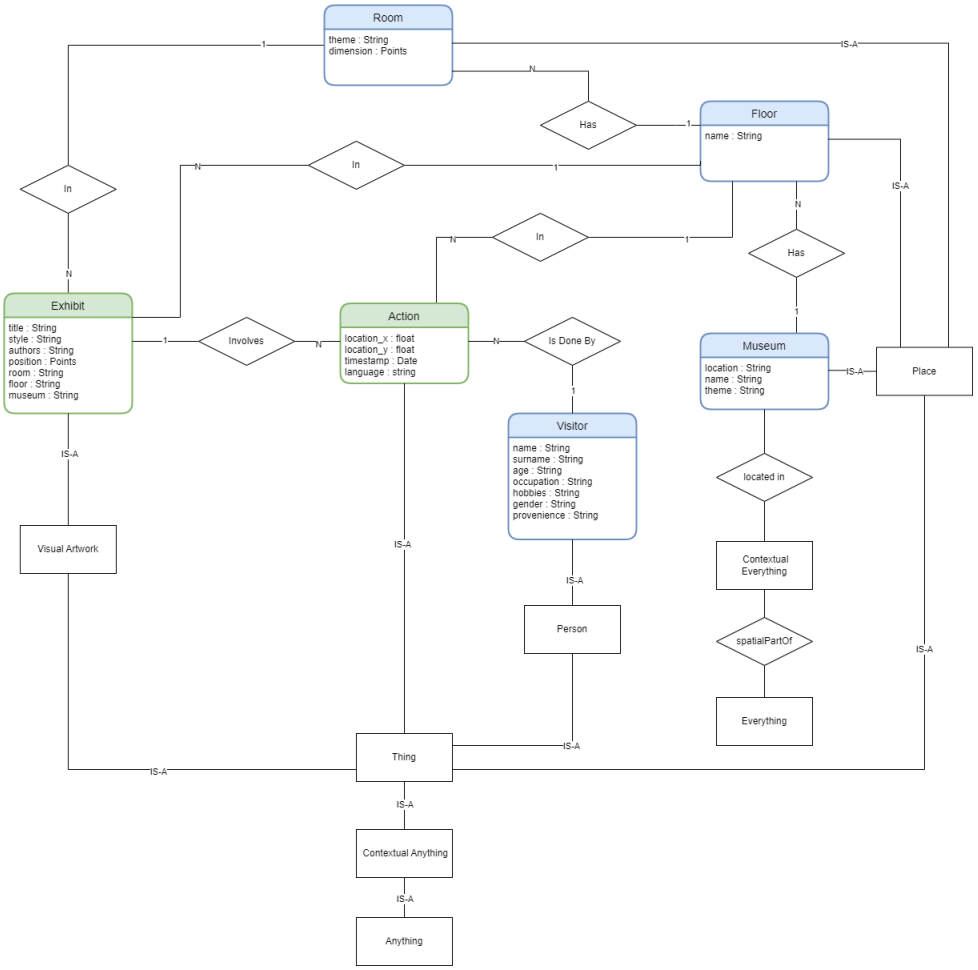


Figure 5: Complete teleontology

7.1 Language Alignment

To formalize the terms used to build the KG, we uploaded the teleontology file on the KOS platform; we were then able to better define the meaning of the entities' properties with universal annotation that are going to help with the increase of the re-usability of resources. All the definitions are in English.

7.2 Data Alignment

After having set the ETG we decided that more formatting and cleaning of the data was needed in order to align the datasets with the teleontology created with Protégé.

The main problem regarded "Action" as there were many entries where the person was in front of an exhibit for a given time, this was not really useful as the timestamp was expressed in milliseconds. We decided to keep only the data that showed what a person is watching and when he/she is starting to look at other exhibits or changing floors. Therefore, a new smaller dataset was produced where all the redundant data was eliminated.

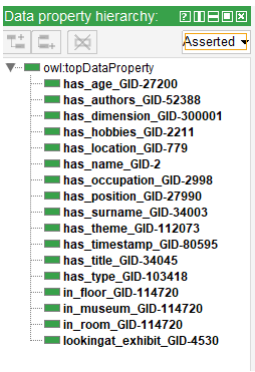


Figure 6: Language alignment of data properties produced through KOS

7.3 Open Issues

After completing the project on KOS, we made some changes to our ETG. For example, we changed at the last some of the properties, added others and changed the links between the entities as it seemed to us a choice more in line with our purpose. So it was not possible to go back and fix the language alignment.

In the first draft of the object properties we had:

- contains
- doing
- has_answered
- has
- is_in
- is_looking_at
- located_in
- SpatialPartOf
- visting

In the second draft we have removed:

- doing
- has_answered
- is_looking_at
- located_in
- visting

But we added:

- is_done_by
- involves
- in

The final object properties are:

- contains
- has
- is_done_by
- involves
- in
- SpatialPartOf

These properties are not too different from the first ones we used but they are much more specific and help us to respond correctly to our CQs.

There are also some difference in the data properties. For example, in the first draft we have ”has_dimension”, but in order to correctly model it to Karma modifyied the teleontology by adding ”dimensiom_xn” and ”dimension_yn” for each of the dimension of the room; the same for location. To be more precise we also added ”has_latitude” and ”has_longitude”

8 KGC

8.1 Data mapping

Thorough all the dataset all the entities were identified by numerical (and incremental) identifiers, which, if used as URI of the entity, caused them to be non unique. To solve this issue we modified the id of each entity representing the type of the entity to the id, for example an entity ”Exhibit” with id 5 would then have its id changed to ”exhibit_5”.

8.2 Entity matching

Some of the entities presented itself in other dataset, presenting us with the problem of semantic heterogeneity. For example, in ”Floor” there is ”Museum” present, and in ”Room” there is ”Floor” present. In order to solve this conflict, we used Karma integration tools. This tools allowed the creation and the modification of datasets attributes in order to build up identifiers through the ”URI of Class”. It is a semantic type mapping used to define a URI identifier for all the entities of a specific etype.

After having resolved all those conflict, we can confidently say that theoretically the KG could answer all the CQs we defined earlier; in fact, all the queries proposed could be answered by the entities and their properties.

9 Outcome Exploitation

Thanks to the previous steps a KG was produced, in order to visualize it and to exploit it GraphDB was used.

9.1 KG Information

For this project, 6 entities were created, namely Visitor, Museum, Floor, Room, Action and Exhibit; each of these entities has their own dataset. To connect among classes 6 object properties were set, they are contains, has, in, involves, is_done_by, SpatialPartOf. After having set entities and object properties, we created 30 data properties.

We are aware that our KG is composed of few entities, but being our DOI inside a museum greatly reduces the CQs possible and consequently the entities extracted.

This KG is very specific and therefore the problem of reuse comes into play. The structure could be used by other museums for a similar purpose, but some changes would be necessary. In the next chapter open issues with this KG will be further investigated.

9.2 Exploitation

This KG can be exploited with GraphDB as with the visualization section one can see the graph and expand the nodes and with SPARQL queries can be performed. Therefore, the CQs can be satisfied with a quick script.

The following figure is an example of what can be visualized in the visualization part

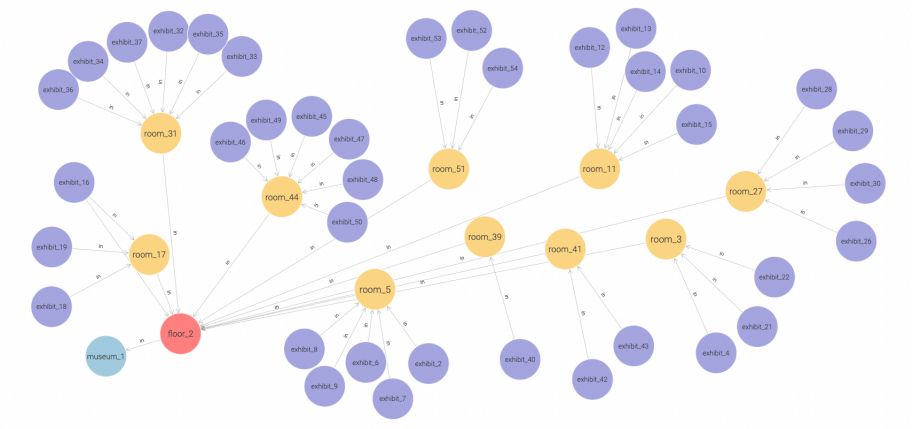


Figure 7: graph visualization example

The graph depicted shows all the exhibits present on the floor ”Primo Piano” (URI floor_2) divided into the respective rooms.

In this section, one can see some screenshots of the queries performed and their outputs. The queries are based on the competency questions previously described.

9.2.1 Search the authors featured in the museum

```
PREFIX p: <https://knowdive.disi.unitn.it/etype#>
PREFIX source: <http://localhost:8080/source/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

select ?authors where {
    ?museum a p:Museum ; p:has_name "Ca' Rezzonico" .
    ?floor rdf:type p:Floor ; p:in ?museum .
    ?room rdf:type p:Room ; p:in ?floor .
    ?exhibit rdf:type p:Exhibit ; p:in ?room ; p:has_authors ?authors .
}
```

1	"Anton Raphael Mengs"
2	"Gaspare Diziani"
3	"Canaletto"
4	"Giandomenico Tiepolo"
5	"Francesco Guardi"
6	"Andrea Brustolon"
7	"Giambattista Tiepolo"
8	"Rosalba Carriera"
9	"Giusto Le Court"
10	"Alessandro Vittoria"
11	"Pietro della Vecchia"
12	"Alessandro Longhi "

9.2.2 Search the authors that are painters

```
PREFIX p: <https://knowdive.disi.unitn.it/etype#>
PREFIX source: <http://localhost:8080/source/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
select distinct ?authors where {
    ?museum a p:Museum ; p:has_name "Ca' Rezzonico" .
    ?floor rdf:type p:Floor ; p:in ?museum .
    ?room rdf:type p:Room ; p:in ?floor .
    ?exhibit rdf:type p:Exhibit ;
             p:in ?room ;
             p:has_authors ?authors ;
             p:has_type "Painting/Fresco" .
    filter(!regex(str(?authors),"Unknown"))
}
```

"Anton Raphael Mengs"
"Gaspare Diziani"
"Canaletto"
"Giandomenico Tiepolo"
"Francesco Guardi"
"Alessandro Longhi "
"Luca Carlevarijs"
"Pietro Longhi"
"Rosalba Carriera"
"Gianantonio Guardi"
"Giambattista Piazzetta"
"Gian Antonio Pellegrini"

9.2.3 Search the floor and room of all the paintings

```
PREFIX p: <https://knowdive.disi.unitn.it/etype#>
PREFIX source: <http://localhost:8080/source/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

select ?title ?y ?x where {
    ?museum a p:Museum ; p:has_name "Ca' Rezzonico" .
    ?floor rdf:type p:Floor ; p:in ?museum .
    ?room rdf:type p:Room ; p:in ?floor .
    ?exhibit rdf:type p:Exhibit ; p:in ?room ; p:has_type "Painting/Fresco" .
    ?exhibit p:location_y ?y ; p:location_x ?x ; p:has_title ?title .
}
```

title	y	x
"Carlo Rezzonico, papa"	"928"	"2592"
"La sagra di Santa Marta"	"1632"	"1678"
"Canaletto, Capriccio architettonico"	"1640"	"900"
"Il falchetto"	"1870"	"2482"
"Il Mondo Nòvo"	"1978"	"2848"
"Il Ridotto"	"1770"	"834"
"Un ritratto di Alessandro Longhi"	"1766"	"771"
"Due capolavori di Canaletto"	"1178"	"1714"
"Capriccio con porto fluviale"	"1630"	"1138"
"Il rinoceronte"	"1028"	"841"
"Il Parlatorio"	"2232"	"822"
"Nel giardino di Armida"	"1916"	"2072"
"Una Madonna di Rosalba"	"840"	"3062"
"Ritratto del maresciallo Matthias von Schulenburg"	"1190"	"670"
"Giambattista Piazzetta"	"1180"	"1028"
"Gian Antonio Pellegrini"	"1168"	"1386"
"Passeggiata e Minuetto"	"2180"	"2602"
"I Pulcinella"	"2230"	"3198"
"Jacopo Amigoni"	"2268"	"3106"

9.2.4 Search the location of all the paintings of a specific author

```
PREFIX p: <https://knowdive.disi.unitn.it/etype#>
PREFIX source: <http://localhost:8080/source/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

select ?floor ?room where {
    ?museum a p:Museum ; p:has_name "Ca' Rezzonico" .
    ?floor rdf:type p:Floor ; p:in ?museum .
    ?room rdf:type p:Room ; p:in ?floor .
    ?exhibit rdf:type p:Exhibit ;
             p:in ?room ;
             p:has_authors "Andrea Brustolon" ;
             p:has_type "Painting/Fresco" .
}
```

floor	room
http://localhost:8080/source/floor_2	http://localhost:8080/source/room_44

9.2.5 List the rooms that have an exhibit of type furniture

```
PREFIX p: <https://knowdive.disi.unitn.it/etype#>
PREFIX source: <http://localhost:8080/source/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

select distinct ?room where {
    ?museum a p:Museum ; p:has_name "Ca' Rezzonico" .
    ?floor rdf:type p:Floor ; p:in ?museum .
    ?room rdf:type p:Room ; p:in ?floor .
    ?exhibit rdf:type p:Exhibit ; p:in ?room ; p:has_type "Furniture" .
}
```

http://localhost:8080/source/room_3
http://localhost:8080/source/room_11
http://localhost:8080/source/room_17
http://localhost:8080/source/room_27
http://localhost:8080/source/room_51
http://localhost:8080/source/room_5
http://localhost:8080/source/room_93
http://localhost:8080/source/room_23
http://localhost:8080/source/room_31
http://localhost:8080/source/room_41
http://localhost:8080/source/room_44
http://localhost:8080/source/room_91
http://localhost:8080/source/room_78

9.2.6 List the exhibit inside a specific room

```
PREFIX p: <https://knowdive.disi.unitn.it/etype#>
PREFIX source: <http://localhost:8080/source/>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>

select distinct ?exhibit where {
    ?museum a p:Museum ; p:has_name "Ca' Rezzonico" .
    ?floor rdf:type p:Floor ; p:in ?museum .
    ?room rdf:type p:Room ; p:in ?floor ; p:has_name "Sala degli arazzi" .
    ?exhibit rdf:type p:Exhibit ; p:in ?room .
}
```

1	http://localhost:8080/source/exhibit_19
2	http://localhost:8080/source/exhibit_18
3	http://localhost:8080/source/exhibit_16

10 Conclusions & Open Issues

All of the deadline set for the project were respected and done in time. Nevertheless, we faced some issues, mainly regarding the Data Integration phase on Karma.

- After having created the TTL files with Karma, we later imported them on graphDB but we incurred a major problem with the visualization. The graph was created, but the different entities had more than one associated E-Type. Museum, for example, should only be museum and instead had also associated the E-Type Floor and Action, therefore it was impossible to have a correct graph in line with the purpose. We did go back to Karma to try and fix it from there, but the same error occurred. We later try to directly modify the RDF files produced by Karma and this time the graph worked as it should. Even though it work this is technically a workaround and conceptually wrong. It's important to mention that the queries work just as they should
- As mentioned in the formal modeling phase, we have a problem with the language alignment as we could not access KOS to apply the same changes we have made to our teleontology

To conclude, we can confidently say that the purpose was satisfied. Our KG is able to show the action performed by the visitors of the museum, thus being able to understand the different visiting behaviours and show the most view parts.