Supporting the Discovery and Reuse of Digital Content in Creative Industries using Linked Data

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***Abstract*—Creative industries play an important role in today's economy, being sources of growth that boost future development. Their products have a huge potential to be re-used and re-purposed, while at the same time they can enrich and improve the design process and create newly exploitable content. This short paper presents V4Link, a semantic annotation and linking framework of multimodal annotations deriving from visual and textual analysis of digital content. The framework reuses the Web Annotation Data Model to capture the annotations, while it semantically enriches the generated knowledge graphs by defining links to Linked Datasets, offering to users advanced query capabilities beyond the ones that can be supported on top of the initial multimodal knowledge base. We illustrate the capabilities of the framework presenting a number of use cases that inspire and support the design, architecture, as well as the 3D and VR game creative industries.**

***Keywords*—Semantic Representation, Linked Data, Semantic Retrieval, Semantic Search.**

I. Introduction

Architecture and Virtual Reality (VR) game design are two of the most highly competing and demanding sectors that can benefit from the available digital content. The high-consumer demands in these sectors require from designers to be constantly creative and multi-skilled, adapted to the latest technology and coupled with strong presentational skills. In this quest, the leverage of existing digital content can drastically speed up the time to market and serve as sources of inspiration towards innovative designs and new concepts. For example, architects can be inspired by existing architecture and related spatial elements of landscapes or historical buildings to design surrounding elements, such as facades, during the architectural design procedure in 3D environments.

In this context, the H2020 project V4Design[1] aims to exploit state-of-the-art technological means so as to re-use and re-purpose existing heterogeneous multimedia content and inspire the design, architecture, as well as 3D and VR game industries. More specifically, V4Design enables the re-use and re-purpose of multimedia content by proposing innovative solutions to extract 3D representations and VR game environments. This allows architects, designers and video game creators to re-use heterogeneous archives of already available digital content and re-purpose it by making the wealth of 3D, VR, aesthetic and textual information easily accessible and providing resources and tools to design and model outdoors and indoors environments of architecture and VR video game projects.

The enrichment of designers' toolkits and workflows with multimodal data (e.g. visual and textual) from various sources can serve as a trigger for inspiration. However, the representation and integration of such information by itself is not adequate to serve as a catalyst for innovative creations and assist the creative industries in sharing content and maximize its exploitation. The retrieval and repurposing of content demands intelligent mechanisms and novel approaches for knowledge interlinking and contextual enrichment to facilitate its discovery and integrate it into the design process.

In this short paper we propose V4Link, a framework for combining and further linking the extracted metadata of the V4Design technologies, so as to generate rich knowledge graphs and support designers in discovering assets using contextual information, such as architectural style, type of building, distance from water (using Linked Datasets), creator, height, number of walls, etc. To achieve this, the framework maps incoming multimodal information to the V4Design conceptual model that follows the Web Annotation Data Model (WADM) [1]. The results are stored in the Knowledge Base, where rules are applied for knowledge enrichment through logical inferences. A semantic querying framework executes the appropriate queries into the local Knowledge Base and Linked Data interfaces (DBpedia and LinkedGeoData) to detect buildings that meet the respective criteria.

The contribution of our research is summarized in the following:

- We describe the annotation model that follows and extends WADM for semantically representing the data.
- We define a set of rules to extract useful inferences and generate hidden knowledge.
- We propose a combination of Linked Data with local knowledge to support useful domain-specific queries.

The rest of the paper is organized as follows. Section II provides a literature review on issues related to semantic representation and Linked Data. Section III presents the methodology of our work, the heterogeneous data sources and the way they are semantically represented. Section IV describes example use cases. Section V presents evaluation results and section VI concludes this work and reports possible future steps.

[1] https://v4design.eu/

II. Related Work

Semantics and Linked Data are the appropriate means to expand the knowledge over specific domains, like for instance cultural heritage. Over the last decades, progress has been made on retrieving knowledge over cultural heritage objects by taking advantage of the capabilities that Linked Data offer [2]. In [3] the scope is to represent geospatial resources that change over time under the cultural heritage domain, while in [4] a framework has been developed that applies semantic annotation and search over cultural heritage resources. To this end, they use the ClioPatria software, semantic web libraries, SPARQL API and graph-search API. The mobile application presented in [5] is based on the device GPS and the strength of Linked Data, to detect cultural information that are in close distance. Accessing a digital library by exploiting the capabilities of semantics has been reported in [6]. Most studies [7], [5] conclude that when information from different sources are integrated, semantic retrieval performance is improved and intelligent searching functionalities can be supported.

The big advantage of semantically representing and publishing data in the web is that one can easily retrieve data using semantic queries. Useful interconnections can be created between data, which are gaining value as they are semantically enriched with information coming from different sources. DBpedia[2] is a popular publicly available Knowledge Base that contains an extremely wide range of information which are composed from Wikipedia infoboxes. Another popular database is GeoNames[3], which focuses more on geospatial information like country boundaries, population, etc. LinkedGeoData[4] is a Knowledge Base that makes OpenStreetMap data available using semantic queries. Data are mostly oriented in the geolocation of different types of buildings. Another popular source of information is the Europeana Data Model (EDM)[5]. The model is based on cultural heritage objects coming from digitised museums, libraries and archives.

V4Link aims to provide a practical content interlinking framework on top of the V4Design multimodal platform (see section III for more details on the available metadata), able to facilitate advanced, context-aware discovery of 3D assets taking into account: a) local relationships and interconnections stemming from the multimedia analysis components, e.g. aesthetics extraction, and b) links to external Linked Datasets, semantically enriching the local knowledge graphs.

III. V4Link Knowledge Graphs

The conceptual architecture of V4Link is depicted in Figure 1. Input is coming from multimodal analysis, such as Shot Detection and Text Analysis. The incoming information is semantically represented, following the annotation model that we describe later in this section. Knowledge is further enriched using domain-specific rules and external sources, namely DBpedia and LinkedGeoData, in the form of semantic queries.

[2]https://wiki.dbpedia.org/
[3]https://www.geonames.org/
[4]http://linkedgeodata.org/About
[5]https://pro.europeana.eu/page/edm-documentation

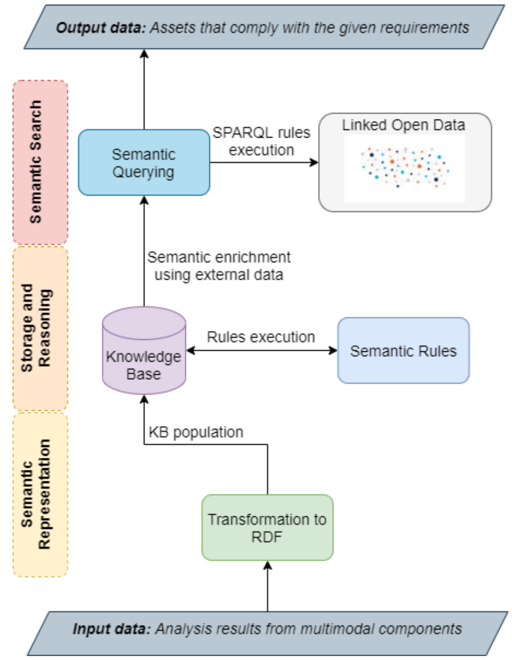

Fig. 1. The overall framework architecture

The output of this pipeline is the set of assets that fulfil the searching criteria, such as 3D models of buildings.

V4Design integrates a number of multimodal analysis techniques. A brief description for each component is found below:

- **Text Analysis** detects key entities (disambiguated) in captions and descriptions. Information is mostly related with the DBpedia URIs, language, additional triples from Wikipedia analysis, etc.
- **Aesthetics Extraction** analyses the aesthetics of a painting and matches information like the creator, style and the emotion that each painting cause to the viewer.
- **Spatio-Temporal Building and Object Localisation** (STBOL) detects the type of building or object (e.g. castle, furniture), along with masks.
- **Building Information Model** [8] (BIM) information is made available regarding the 3D model topology, such as floors count, ceilings count, roofs count, walls count, etc.
- **3D Model Reconstruction** reconstructs the 3D model that comes from a video or set of images. V4Link integrates and attaches to the 3D models all the relevant metadata extracted through the above mentioned multimodal analysis techniques.

A key design choice underpinning the engineering of the V4Link knowledge graphs is the adherence to an existing standard so as to capitalise on a modular, extensible and interoperable framework for expressing annotations and achieve a better degree of knowledge sharing, reuse and interoperability. In particular, we use the Web Annotation Data Model, where an annotation is considered to be a set of connected resources, typically including a body and target, and conveys that the body is related to the target. The exact nature of this relationship changes according to the intention of the annotation,

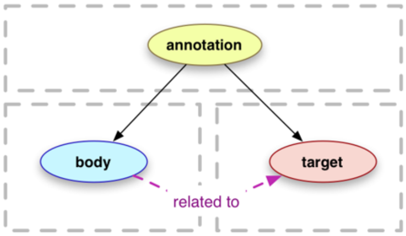

Fig. 2. The core Web Annotation Data Model pattern.

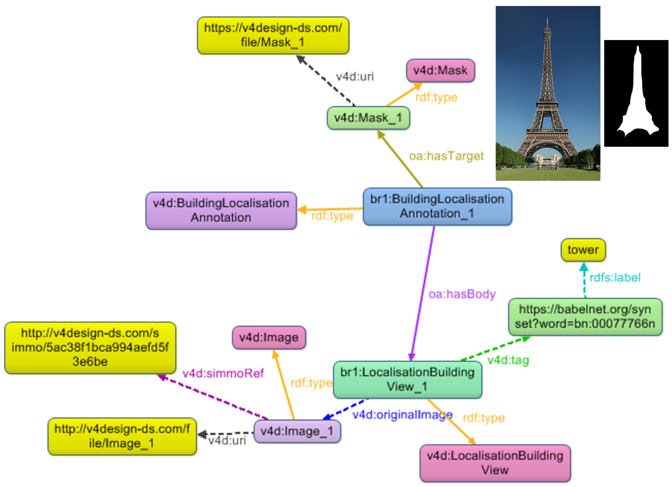

Fig. 3. Example of semantic representation of building localisation.

but the body is most frequently somehow "about" the target (Figure 2).

As an example, we present the generated knowledge graph for localising the Eiffel Tower in an image. More specifically, the mask is generated for the building that is further with a tag (*tower*). Following the WADM model, a v4d:BuildingLocalisationAnnotation resource is generated that is linked with the *target* of the annotation, i.e. the generated mask (Mask_1) and the *body* annotation view (BuildingLocalisationView_1). The latter, defines property assertions relevant to the original image where this mask has been extracted from (Image_1), as well as the relevant tag which is the BabelNet resource for the concept "tower". The figure also depicts additional descriptive properties relevant to id references in the underlying data storage.

IV. Context-aware Search

Since DBpedia entities are already available from the multimodal analysis pipeline, e.g. from text analysis, we capitalise on this entity to extract more information of architectural nature related to each asset, such as architectural style, creator, etc. Additionally, we take advantage of the DBpedia entities to access LinkedGeoData. Using LinkedGeoData further enriches the Asset information with geolocation information as detecting the proximity between an asset and other points of interest is feasible. More specifically, each asset contains one main entity from DBpedia. The following scenarios run for all the asset–entity couples and detect assets that comply with the given criteria, taking advantage of the Linked Data dynamics. The field $< entity >$ represents the main entity which may be for instance $< http://dbpedia.org/resource/Toronto\_City\_Hall >$.

In this section we describe two different scenarios that illustrate the way V4Link can assist in the design process.

1) Scenario 1: Proximity to Point of Interest (POI): The aim in to detect assets that are close to a specific type of POIs, such as Museums, Water objects, Archaeological Sites, etc. This type of query has been specifically requested by the users, as it allows them to retrieve assets and being inspired based on surrounding information. To this end, we combine the DBpedia entities that are extracted by analysing the captions and descriptions of multimedia content, and LinkedGeoData (lgdo). The query (Listing 1) uses the objects' geometries and the bif:st_intersects function that detects whether the two geometries (geom) are within a radius of one kilometer. The first geometry is defined using the DBpedia entity that has been detected in text analysis procedure, while the latter is defined by a class which in this case is a lgdo:Museum. The same query is applied to detect the proximity of a building to hydrographic network objects or other types structures of architectural interest i.e. Archaeological Sites, Art Centres, Attractions, etc. using in each case the corresponding classes. The type of POI and distance vary according to the criteria that are defined by each user.

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX lgdo: <http://linkedgeodata.org/ontology/>
PREFIX geom: <http://geovocab.org/geometry#>
PREFIX ogc: <http://www.opengis.net/ont/geosparql#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX bif: <bif:>
SELECT * WHERE{
  ?s owl:sameAs <entity>;
    geom:geometry [ogc:asWKT ?sg] .

  ?x a lgdo:Museum;
    rdfs:label ?l; geom:geometry [ogc:asWKT ?xg].
    FILTER(bif:st_intersects (?sg, ?xg, 1)) .
} LIMIT 1
```

Listing 1. Example of semantic query to decide whether a building has Museums in an 1 kilometer distance using LinkedGeoData

2) Scenario 2: Architecture-related requirements: In this scenario the scope is to detect assets by integrating multimodal information, e.g. they have a specific architectural style or creator, belong to a specific building type, have been renovated or not. In the following query (Listing 2) we detect whether a building has not been renovated, taking advantage of the wide range of information and properties that DBpedia offers. We detected several different properties such as dbp:restored, that express the date of renovation for a DBpedia entity. To implement this query, we took advantage of the different properties that are provided by DBpedia and the FILTER NOT EXISTS function of SPARQL.

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX dbp: <http://dbpedia.org/property/>
SELECT * WHERE {
    FILTER NOT EXISTS {
        <entity> dbp:restored ?ren_date0. }
    FILTER NOT EXISTS {
        <entity> dbp:dateRenovated ?ren_date1. }
    FILTER NOT EXISTS {
        <entity> dbp:renovationDate ?ren_date2. }
    <entity> ?property ?value.
```

```
} LIMIT 1
```

Listing 2. Example of querying DBpedia to detect non-renovated buildings

In cases that we want to detect a specific architectural style, we combine information coming from the local Knowledge Base with Linked Data. More specifically, as presented in Listing 3 the query searches among a list of different types of properties that express the architectural style, whether a specific entity follows the selected style. This query is running on DBpedia data. Since not all DBpedia properties exist on each entity, we use the OPTIONAL function of SPARQL to execute this query and detect all the different architectural style values that may exist for each entity.

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX : <http://dbpedia.org/resource/>
PREFIX dbp: <http://dbpedia.org/property/>
PREFIX dbo: <http://dbpedia.org/ontology/>
SELECT * WHERE {
OPTIONAL {
    <entity> dbp:architectureStyle ?style0.
    ?style0 rdfs:label ?ast1. }
OPTIONAL {
    <entity> dbp:style ?style1.
    ?style1 rdfs:label ?ast2. }
OPTIONAL {
    <entity> dbo:architecturalStyle ?style3.
    ?style3 rdfs:label ?ast3. }
OPTIONAL {
    <entity> dbp:architecture ?style4.
    ?style4 rdfs:label ?ast4. }
OPTIONAL {
    <entity> dbp:architecture ?ast5.
    FILTER NOT exists {?ast5 rdfs:label ?style5.} }
FILTER (regex(str(?ast1),"Baroque") ||
  regex(str(?ast2),"Baroque") || regex(str(?ast3),"Baroque") ||
  regex(str(?ast4),"Baroque") || regex(str(?ast5),"Baroque") )
FILTER (langMatches(lang(?ast1),'en') && langMatches(lang(?ast2),'en')
  && langMatches(lang(?ast3),'en') && langMatches(lang(?ast4),'en') )
}
```

Listing 3. Example of querying DBpedia to detect buildings with Baroque architectural style

V. Evaluation

In Table I we display the execution time in seconds of transforming incoming annotations into the V4Link annotation model. The modality that needs the most time to be mapped and stored in the RDF triple store (we have use the free version of GraphDB[6]) is the 3D model reconstruction, while BIM information is handled more efficiently. This is mainly because BIM does not require any additional mapping logic in the form of inference/integration rules, while the 3D model reconstruction assets serve as main resources that need to be associated with all the available metadata.

TABLE I
Mean execution time of semantic representation, storage and reasoning per component

Component	Execution time in seconds
Text analysis	1.87
Aesthetics extraction	0.92
STBOL	1.72
3D Model Reconstruction	1.99
BIM	0.55

In Table II we present the mean execution time per scenario execution. The calculation has been applied in a set of 681 Assets, where 163,966 triples exist. The conclusion of this process is that execution time increases rapidly when querying in Linked Data is applied or there is a large amount of triples. The number of properties that appear in the queries seems to also increase execution time, as in cases like architecture-related requirements, there is a large number of properties and execution time is also high.

[6]https://graphdb.ontotext.com/

TABLE II
Mean execution time of semantic search based on each scenario

Scenario	Mean execution time in seconds
Proximity to POI	11.17
Architecture-related requirements	13.72

VI. Conclusion

In this short paper, we described V4Link, a framework that takes advantage of Linked Data capabilities to support designer (such as architects and video game designers) to intelligent discovery of assets. Data coming from multimodal components is mapped to RDF graphs following the Web Annotation Data Model and is coupled with popular Linked Data datasets, namely DBpedia and LinkedGeoData. User-driven queries are then executed to assist the design process. The evaluation showed that the semantic representation, reasoning and storage has low execution time, while the execution time of semantic search is strongly affected by the usage of Linked Data.

Future work includes the detection of different Linked Data datasets which can be used to support scenarios that are not included in the current version of this framework. Additional properties of the existing datasets may also be examined. The scenarios may be updated accordingly to meet the needs of the users.

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References

[1] R. Sanderson, P. Ciccarese, and B. Young, "Web Annotation Data Model," *W3C*, pp. 1–56, 2016. [Online]. Available: https://www.w3.org/TR/annotation-model/

[2] K. N. Vavliakis, G. T. Karagiannis, and P. A. Mitkas, "Semantic web in cultural heritage after 2020," in *Proceedings of the 11th International Semantic Web Conference (ISWC), Boston, MA, USA*, 2012, pp. 11–15.

[3] T. Kauppinen, J. Väätäinen, and E. Hyvönen, "Creating and using geospatial ontology time series in a semantic cultural heritage portal," in *European Semantic Web Conference*. Springer, 2008, pp. 110–123.

[4] G. Schreiber, A. Amin, L. Aroyo, M. van Assem, V. de Boer, L. Hardman, M. Hildebrand, B. Omelayenko, J. van Osenbruggen, A. Tordai *et al.*, "Semantic annotation and search of cultural-heritage collections: The multimedian e-culture demonstrator," *Journal of Web Semantics*, vol. 6, no. 4, pp. 243–249, 2008.

[5] C. Van Aart, B. Wielinga, and W. R. Van Hage, "Mobile cultural heritage guide: location-aware semantic search," in *International Conference on Knowledge Engineering and Knowledge Management*. Springer, 2010, pp. 257–271.

[6] A. Baruzzo, P. Casoto, P. Challapalli, A. Dattolo, N. Pudota, and C. Tasso, "Toward semantic digital libraries: Exploiting web2. 0 and semantic services in cultural heritage," *Journal of Digital Information*, vol. 10, no. 6, p. 4, 2009.

[7] R. Guha, R. McCool, and E. Miller, "Semantic search," in *Proceedings of the 12th international conference on World Wide Web*, 2003, pp. 700–709.

[8] R. Volk, J. Stengel, and F. Schultmann, "Building information modeling (bim) for existing buildings—literature review and future needs," *Automation in construction*, vol. 38, pp. 109–127, 2014.