Journal of Visual Languages and Computing 25 (2014) 1012–1020

Contents lists available at ScienceDirect

Journal of Visual Languages and Computing

journal homepage: www.elsevier.com/locate/jvlc

Interacting with annotated objects in a Semantic Web of Things application ☆

Mauro Coccoli *, Ilaria Torre

Department of Informatics, Bioengineering, Robotics, and Systems Engineering, DIBRIS – University of Genoa, Genoa, Italy

ARTICLE INFO

Article history:
Received 20 September 2014
Accepted 24 September 2014
Available online 2 October 2014

Keywords:
Technology enhanced learning
Semantic web
Linked open data
Internet of things

ABSTRACT

This paper presents a model and an infrastructure for technology-enhanced learning applications and discusses issues in using Semantic Web, Linked Data, and Internet of Things. In particular, we apply the novel paradigm of the Semantic Web of Things to enhance information management and users' experience in a museum exhibition where artworks assume a proactive role and provide visitors with enriched information. According to the Linked Data principles, the content delivery system is empowered by the introduction of suited semantic annotations to the objects. This enables things in the real world to be linked to their corresponding descriptions on the Web of Data and, in turn, it enables users to increase their knowledge and discover new facts. Moreover, the deployment of education-oriented annotations, which specify how to use the sensorized objects in learning activities, makes possible to match their features with educational tasks and users characteristics, thus providing personalized services and improving the learning experience.

1. Introduction

The investigation of the Semantic Web (SW) capabilities is a challenging item for future Internet applications and is a hot research topic too. Nowadays, a minor part of available web resources are based on the SW paradigm and, currently, it is difficult to find data in standard formats, due to both data providers and web designers attitudes. Furthermore, in most situations, the description of relationships between data is still lacking. However, programmers can rely on a full-featured suite of SW technologies for writing and querying the Web and this outlines a scenario ready for semantics, where relationships between data are expressed clearly and information can be linked accordingly. In particular, the Linked Data (LD) principles provide a publishing paradigm in which structured data can be easily exposed, shared and linked. Sharing common languages, publishing methods and tools, as well as ontologies, enables semantic search engines to effectively retrieve information associated to such linked data and provide advanced services to users [1]. In this scenario, embedding semantic annotations into real world objects, locations and events and making them available over the Web is a fascinating perspective that goes under the name of Semantic Web of Things (SWOT).

Such a technological solution can be exploited in many fields of application and it is very attractive from the viewpoint of technology-enhanced learning. In fact, by interacting with objects, learners can acquire knowledge and abilities in a natural fashion and find relations with other objects and data, driven by logical connections. Moreover, as objects are part of a SWOT framework, they contain information that can be further enriched with new data, retrievable from the Internet by means of suited queries. Besides, the possibility for learners to interact with things in the surrounding environment can be exploited in the perspective of the *experiential learning* [2], that is the process of learning and making meaning from direct experience. In this fashion, SWOT can become an educational platform and a methodology that takes the benefits of both inductive and deductive educational

☆ This paper has been recommended for acceptance by S.-K. Chang.

* Corresponding author at: University of Genoa, Department of informatics, Bioengineering, Robotics, and Systems Engineering, Via Opera Pia 13, 16145 Genova, Italy. Tel.: +39 0103532736.
E-mail addresses: mauro.coccoli@unige.it (M. Coccoli), ilaria.torre@unige.it (I. Torre).

http://dx.doi.org/10.1016/j.jvlc.2014.09.008
1045-926X/

approaches, the former coming from the interaction with objects and the latter coming from the semantic network of concepts relating to objects.

Specifically, in this paper we describe an application based on the use of contactless technologies in a museum exhibition, which makes possible the interaction between users and the art works exposed therein [3,4]. To enrich this setup with educational features, we have added semantic annotations to the artworks and we have used this setting to provide augmented and personalized information, according to the framework described in [5]. For the annotation of artworks we have adopted the Europeana open data model [6] and we have extended it with properties for educational purposes from LRMI (Learning Resource Metadata Initiative) specification. Semantic annotation can thus be exploited by users to investigate on related objects in the Web of Data such as, e.g., to get additional information about the author of a specific piece as well as on the historical period, and so on, based on both the links included within the linked data and the specific learning goals and tasks.

Summarizing, the objective of this paper is describing an application scenario for significant experimentations with SWOT in education. Currently, the state of the art in this research field lacks of tangible results and the contribution of this project is providing a working proof of concept to push the adoption of such technologies in this area.

The remainder of the paper is organized as follows: in Section 2, related works are presented with reference to SW and the use of SW and Internet of the Things (IoT) in education; Section 3 describes the reference scenario selected for the sample application; Section 4 deals with the annotation process; Section 5 reports the interaction workflow with objects. Finally, conclusions are presented in Section 6.

2. Related work

Given their relevance, coverage and popularity, we introduce this section by mentioning a set of ontologies often linked by other datasets. One of the most common is DBpedia[1], which adds meanings, expressed through links, to the information included in Wikipedia, the renowned free encyclopedia. Another relevant ontology is YAGO, developed within the yago-naga project [7], based on a larger dataset, including Wikipedia and other databases like Wordnet[2] for a clean lexical taxonomy, Geonames[3] for geographical information, and WordNet Domains[4] to the aim of achieving a better categorization. The third example that is worth to mention is the Freebase[5] project, which is described as a "community-curated database of well-known people, places, and things". Essentially, it is an open collection of data and connections between them, in which topics are organized by type and people can freely connect pages with links and semantic tagging.

The W3C website[6] provides information and comparisons about RDF triple stores, storage managers and semantic tools to support the use of structured data, thus transforming them into an effective and more powerful source. In particular, a useful benchmark analysis is available, about storage managers for storing large-scale RDF data sets.

The current situation of SW applications is discussed in [8], which analyses discoverability, interoperability and efficiency of available public SPARQL end-points. However, this topic is continuously evolving and a glance on future applications is given in [9], which focuses on the problem of browsing and searching the SW from mobile devices and wearable computers too.

To conclude this general overview on the SW, we note that W3C maintains a featured list of applications based on the use of SW technology, including both use case and case studies[7]. Among these, we mention the case of British Broadcasting Company (BBC), which has one of the most successful applications of SW technologies and was one of the first organizations to use LD.

2.1. Semantic Web and education

The current web is a fundamental source of information in both school and universities and can be even the only resource such as, for example, in some lifelong learning projects. It can greatly benefit from the adoption of solutions based on the Semantic Web infrastructure and, especially, LD can empower technology-enhanced learning [10]. This results in an Educational Semantic Web [11] where information can be managed, shared and retrieved in a more effective way.

Beside the traditional use of SW technologies to annotate learning materials following a top-down approach, a more recent one concerns the annotation of user-generated content (UGC). The possibility to annotate UGC with contextual metadata, showing the benefits of classifying digital content that emerge during learning processes and activities is presented in [12]. This approach, based on merging semantic and social web to improve the retrieval of education resources is analyzed also in [13]. The authors propose a specific architecture for sharing and retrieving educational resources by using a dataset/repository based on the LD principles.

Following the same approach of combining semantic and social web, but with a focus on the authoring phase of learning activities, semantic technologies have been used in [14] to support collaboration. The author presents a Semantic Web-based authoring tool developed with the aim of facilitating the teachers in planning collaborative learning scenarios, according to consolidated learning models.

Improvements in discovery and retrieval of learning resources are reported in several projects. In [15] the focus is on the former issue, while other authors stress the concept of interoperability, which enhances the possibility of retrieval. Our approach goes along this same line. In [16], for example, the SW technologies are considered as the basis for the construction of e-learning resources and

[1] http://dbpedia.org.
[2] http://wordnet.princeton.edu.
[3] http://geonames.org.
[4] http://wndomains.fbk.eu.
[5] http://freebase.com.
[6] http://www.w3.org/RDF.
[7] http://www.w3.org/2001/sw/sweo/public/UseCases.