

Using Formal Narratives in Digital Libraries

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Abstract. Currently, Digital Libraries (DLs) provide simple search functionalities to respond to the user’s queries, which return a ranked list of the resources included in the DLs. No semantic relation among the returned objects is usually reported that could help the user to obtain a more complete knowledge on the subject of the search. The introduction of the Semantic Web and in particular of the Linked Open Data has the potential of improving the search functionalities of DLs. In this context, the long-term aim of our study has been to introduce the *narrative* as new first-class search functionality of DLs. We intend *narratives* as semantic networks of events that are linked to the objects of the DLs and are endowed with a set of semantic relations that connect an event to another. In this paper, we report an overview of the main ontologies for representing events and of the tools developed in the Semantic Web field to visualize events and narratives. This overview is needed for achieving the first goal of our research, that is the development of an ontology for representing narratives and, on the top of this ontology, a tool to construct and visualize narratives using the digital objects included in DLs.

Keywords: Digital libraries · Narratives · Ontologies · Digital humanities · Semantic web

1 Introduction

Currently, Digital Libraries (DLs) provide simple search functionalities to respond to the user’s queries, expressed in natural language. These functionalities return a ranked list of the resources included in the DLs. No semantic relation among the returned objects is usually reported that could help the user to obtain a more complete knowledge on the subject of the search. For example, consider as user a young woman wishing to know more about Dante Alighieri, the major Italian poet of the late Middle Ages. She may ask “Dante Alighieri” to a Web search engine and most likely she would get a list of ranked documents with the Wikipedia page about Dante within the top 5 results. Not willing to spend her time reading, the user tries other Web sites, where she hopes to find something quicker to consume than the typical textbook narrative. At some point, she tries to search on the Web page of a DL, e.g. Europeana¹. However, the result

¹ <http://www.europeana.eu>.

is a list of objects without any explicit semantic relations to each other. Each object offers a single view of Dante’s life and works, but altogether incapable of providing an complete overview of Dante’s life. This behavior, which generally characterizes DLs, is a consequence of seeing a digital library as a traditional library endowed with digital resources managed by software. The introduction of the Semantic Web [5], and in particular of the Linked Open Data², has the potential of improving the search functionalities of DLs. In this context, the long-term aim of our study has been to introduce the *narrative* as new first-class search functionality of DLs. As output of a query, the envisaged new search functionality should not only return a list of objects but it should also present one or more narratives, composed of events that are linked to the objects of the existing libraries and are endowed with a set of semantic relations connecting these events into a meaningful semantic network. As a necessary and preliminary step towards this direction, this paper presents an overview of the main developed ontologies for formally representing events, along with several tools for their construction and visualization in user-friendly forms, based on semantic models. Indeed, in order to introduce this new search functionality for DLs, we aim at developing: (i) a formal ontology for representing events and narratives, which reuses existing ontologies in order to maximize its interoperability; (ii) a tool that allows users to construct narratives but also to visualize them in an easy and useful way. Information about our project is available at <http://narra.isti.cnr.it>.

2 Ontologies for Representing Events

Narrative is a well-researched concept in several fields, ranging from literary studies to cognitive science. As a matter of fact, “narrative can be viewed under several profiles – as a cognitive structure or way of making sense of experience, as a type of text, and as a resource for communicative interaction” [16]. For the purposes of this research, a narrative is intended as a network of “temporally indexed representations of events” [32], that is events associated to time structures and related to one another and to the DL resources through semantic links.

The concept of *event* is a core element of the narratology theory and of the narratives. People conventionally refer to an *event* as an occurrence taking place at a certain time in a specific location.

In the following, we briefly describe some ontologies developed for representing events on the Semantic Web [4]. Ontologies can be divided into the following categories: upper ontologies and domain ontologies [37]. An upper ontology is a domain-independent ontology, from which more domain-specific ontologies may be derived. A domain ontology specifies concepts, which belong to a specific domain of interest.

² https://www.ted.com/talks/tim_berners_lee_on_the_next_web.

*OpenCyc*³ is the open source version of the Cyc ontology. It is an upper ontology⁴, which is used for representing human knowledge about the objects and events of everyday life. The Cyc knowledge base contains about five hundred thousand terms, including about seventeen thousand types of relations, and about seven million assertions relating these terms. OpenCyc distinguishes between static situations and events. The first ones are situations that are extended in time but do not change, whereas events are situations that are extended and change in time.

The *Suggested Upper Merged Ontology (SUMO)* [36] is a comprehensive upper ontology which is fully mapped to the WordNet lexical database [35]. The ontology has been successfully applied to the representation of narratives, in particular to automated story generation systems [7], and it is has also been used to model the cause-effect relations found in narratives [3].

DOLCE-Lite-Plus is the first module of the WonderWeb Foundational Ontologies Library [30]. DOLCE aims at representing the ontological categories underlying natural language and human common-sense. DOLCE is described as an “ontology of particulars” [30], which the authors explain as an ontology of instances rather than an ontology of universals or properties. Particulars are entities that cannot have instances; universals are entities that can have instances. In linguistics, proper nouns are normally considered to refer to particulars, while common nouns to universals. DOLCE+ is an extension of DOLCE containing some modules dedicated to core ontologies of contexts, time, space, plans etc. The current implementation of DOLCE+ is DOLCE-Lite-Plus. DOLCE-Lite-Plus has been used to align about 900 synsets from the noun hierarchies of the WordNet 1.6 English lexical database. This alignment makes it possible to put the entire 66,000 synsets from WordNet 1.6 (currently about 60,000 classes and 5,000 individuals) under DOLCE-Lite-Plus.

In DOLCE+, “Event” is a subclass of “Perdurant”. “Classically, endurants (also called continuants) are characterized as entities that are in time, wholly present (all their proper parts are present) at any time of their existence. On the other hand, perdurants (also called occurrents) are entities that happen in time, which extend in time by accumulating different “temporal parts”, so that, at any time t at which they exist, only their temporal parts at t are present. Events are called achievements if they are atomic, otherwise they are accomplishments”.

The *CIDOC CRM*⁵ (CRM for short) is a high-level ontology that allows to integrate the information contained in data of the cultural heritage domain along with their correlation with knowledge stored in libraries and archives [13]. The CRM is one of the most widely adopted ontologies in the domain of Cultural Heritage, where both digital libraries and narratives belong. CRM is also an ISO standard since 2006 (ISO21127:2006) and renewed 2014 (ISO21127:2014). Both these factors are crucial to attain semantic interoperability, based on sharing existing ontologies. In CRM, the class “Event”, along with its subclass “Activ-

³ <http://opencyc.org>.

⁴ <http://www.cyc.com>.

⁵ <http://www.cidoc-crm.org>.

ity”, corresponds to the definition of Event in Event Calculus. In the CRM this class “comprises changes of states in cultural, social or physical systems, regardless of scale, brought about by a series or group of coherent physical, cultural, technological or legal phenomena”.

The *Europeana Data Model* (EDM) [14] is a model that aims at structuring and representing data delivered to Europeana⁶ by the various contributing cultural heritage institutions. Europeana is often presented as a portal giving access to millions of objects from all kinds of cultural heritage communities but in [6] it was explained that “Europeana is not so much a portal characterised by sheer volume, but that the core agenda of our endeavour is to make rich data and functionality available on an API basis. This would allow all kinds of external communities to make use of our rich (and numerous) representations of European cultural treasures for their own needs”. In the EDM Primer⁷ two approaches to provide contextual information about objects are reported: object-centric and event-centric. With the former, descriptive meta-data, such for example title or creator, are attached to the provided object. With the event centric approach, relations between different entities are described by means of Events, and meta-data are attached to such events. For example, a piece of art can be related to its creator via a “creation” event, in which the author is specified as the event performer. The two approaches co-exist, so that duplicate and/or complementary information pieces can be provided in both ways.

The *Event Ontology* [38] was developed in the Center for Digital Music of the Queen Mary University of London. This ontology, which can be used in conjunction with other music-related ontologies, has not specific terms related to the music domain so it can be used in other domains as well. The top-level class in the Event Ontology is the class Event. The ontology defines event as “an arbitrary classification of a space/time region, by a cognitive agent. An event may have actively participating agents, passive factors, products, and a location in space/time” [38].

The *Linking Open Descriptions of Events* (LODE) ontology is a “minimal model that encapsulates the most useful properties for describing events” [40]. The aim of LODE is to permit interoperability when modeling the factual aspects of events. Those aspects are characterized in the four aspects: what happened, where did it happen, when did it happen, and who was involved. An event is described as a class that is defined as “something that happened”.

The *Event-Model-F ontology* is mainly focused on the processing of events. The ontology is to be used in event based systems [39]. Its model is “based on the foundational ontology DOLCE+ DnS ultralight⁸ and provides comprehensive support to represent time and space, objects and persons as well as mereological, causal, and correlative relationships between events” [39].

⁶ <http://www.europeana.eu>.

⁷ http://pro.europeana.eu/files/Europeana_Professional/Share_your_data/Technical_requirements/EDM_Documentation/EDM_Primer_130714.pdf.

⁸ <http://www.loa.istc.cnr.it/ontologies/DUL.owl>.

The *ABC ontology* is a basic model and an ontology to facilitate the development of a domain, role, or community specific ontologies, in particular “it is a basic Ontology, which provides a basic model for domain-related or community-related development” [43]. The ABC ontology was developed for modeling physical, digital and analogue objects contained in libraries, archives, and museums and on the Internet [17].

The *Simple Event Model (SEM)* [42] allows representing events in different domains, independently from the domain-specific vocabularies that can be used. An event in SEM is defined as everything that happens, even if fictional. SEM is developed with a minimum of semantic commitment to maximize its interoperability. The core classes of SEM are Event, Actor, Place and Time. These represent the main aspects of an event: what happens, who or what participated, where and when did it happen.

The *Drammar Ontology* is a semantic model for the representation of drama features, featuring a SRWL-based rule layer to provide automatic reasoning [25]. The Drammar model is based on *actions* carried out by *agents*. The core element driving the storyline is the *conflict*, which puts in motion an ordered sequence of actions linked together by causal relations. The actions are grouped in *units*, or narrative blocks. The Drammar ontology is also able to represent the characters’ *emotions*. For the description of its terms, Drammar refers to the YAGO-SUMO ontology [12], i.e. an integration between SUMO and YAGO (Yet Another Great Ontology) [41].

3 Visualization of Narratives in DLs

Narratives have been recently proposed to enhance the information contents and functionalities of DLs, with special emphasis on information discovery and exploration.

For example, in the CultureSampo project [21] an application to explore Finnish cultural heritage contents on the Web, based on Semantic Web technologies was developed. This system uses an event-based model and makes links among events and digital objects. However it does not allow visualizing the event and the related digital objects as a semantic network provided with the semantic relations that connect events and objects but it presents nine “thematic perspectives” [20], e.g. (i) Maps Search and Browse Views, which presents four map views available using Google Maps, and displays, for example, any collection object with coordinate information on Google Maps, and shows the semantic relations of objects with the place, e.g. “place of acquirement”, “place of subject”; (ii) for the Relational Search perspective the idea is not to search for objects but associative relation chains between objects. The user can indicate two names and CultureSampo shows how the persons or organizations are linked to each other by the social network based on some 50 different social roles (e.g., parent-of, teacher-of, patron-of etc.).

An extension of CultureSampo is WarSampo system [18] for publishing collections of heterogeneous data about the Second World War on the Semantic

Web. WarSampo is based on harmonizing different datasets using an event-based model and then, through a dedicated portal, allows historians to study war history from different interlinked perspectives. For example, an user could want to see how an event evolve in time and where it took place, or s/he could be interested in some persons and in their experiences in the war. Providing different perspectives to visualize the collected data allows this system to differ from other portals like Europeana that allows only a single view on its collection.

Narrative event structures and semantic event descriptions were used in end-user applications for searching and linking documents and other content about World War I [19]. Events are related to each others through narrative relations, e.g. sub event relationships that decompose events mereologically; succession relationships that order the events in time; causal relationships. The developed model allows representing multiple narratives that share same events, without mixing the story lines and the different causal relations among the same events cannot be represented, even if different authors may have different opinions about them. A World War I Web portal was developed to facilitate searching and browsing collection data by topics, people, places and time periods, and to visualize the collection metadata in an interactive ways.

Bletchley Park Text [33], a semantic application helping users to explore collections of museums. Visitors express their interests on some specific topics using SMS messages containing keywords. The semantic description of the resources is used to organize a collection into a personalized web site based on the chosen topics. The system relies on an ontology of story, taken from the Story Fountain project [34]. The stories represented in the system are exploited to create relations between the entities contained in the online collections, allowing the user to query the system for a semantic path between entities.

In the PATHS project [15] a system that acts as an interactive personalized tour guide through existing digital library collections was created. A path is a device for ordering, connecting and annotating a series of items of interest that have been collected in a Cultural Heritage digital library. In a path structure, (i) nodes representing items from an online collection or Web pages, which can have associated metadata; (ii) links that represent inheritance relations between nodes allow the navigation across the path; (iii) annotations and external links can added by the path-creator to provide additional context and narrative.

Similar to the approach of PATHS project, within the CULTURA project [1] a tool to enrich the cultural heritage collections with guided paths in the form of short lessons called *narratives* was developed. The system is provided with automatic tools that simulate the research behavior of expert users when they interact with the multimedia application. The experimental results have been obtained using a multimedia application that manages the digital representation of historical manuscripts about botany.

DIVE [11] is a system that allows event-based browsing of cultural heritage objects from two heterogeneous historical Dutch collections (video and and radio news scripts). The collected data is modeled using the Simple Event Model (SEM). A Named Entity Recognition (NER) and Event extraction tools were

adopted in order to retrieve a set of relevant concepts from the metadata and textual description associated to the collected data. In a second stage, crowdsourcing approach was employed to refine the results from Natural Language Processing tools. The results from the different tools and the crowdsourcing are translated into an RDF graph. Then, the graph can be explored using a browser that allows to visualize explicit relation between objects and events.

The Storyspace system [44] allows describing stories based on events that span museum objects. The system is focused on the creation of curatorial narratives from an exhibition. Each digital object has a linked creation event in its associated heritage object story. Kilfeather and McAuley (2003) [22] describe some tools which would facilitate the development of a meaningful story or narrative structure from existing or newly contents. The aim was to allow authors to establish semantic relations between different contents and to select and put them together. The ontology was based on existent taxonomies and thesauri related to Irish archaeology.

DECHO is a framework for the acquisition, ontological representation, and visualization of knowledge about archaeological objects [2]. The ontological component is based on the CIDOC CRM reference ontology. The visualization component has the ability to display narratives by linking together image or 3D representations of archaeological objects via *semantic hotspots* [31].

Another example is the CADMOS suite of applications, developed in conjunction with the Drammar ontology [26]. CADMOS adopts a computer-supported semantic annotation of narrative media objects (video, text, audio, etc.) and integrates with a large common-sense ontology (YAGO-SUMO) [29]. CADMOS also features a visualization tool, which gives a graphical representation of the basic aspects of the narrative [27].

Another ontology-based system for the visualization of narratives is the Labyrinth project [9]. The Labyrinth system allows users to explore digital cultural heritage archives by providing narrative relations among knowledge resources. Labyrinth is not tied to a specific collection of objects, but is instead an open system which allows the emergence of semantic connections among heterogeneous resources [8]. The exploration of the repository is mediated through a set of *cultural archetypes*, or narrative structures, which are modelled according to an Archetype Ontology [23]. More recently, the Labyrinth system has been extended with a three-dimensional interface [10].

A similar project is Invisibilia, which is focused on the domain of contemporary public art [28]. Invisibilia takes as input an ontological representation, constructed using a CRM-based ontology for intangible art [24], and outputs a 3D layout featuring the artworks.

4 Discussion

In order to introduce narratives as new search functionality in DLs and to develop an ontology for representing narratives, first we have analyzed the Artificial Intelligence (AI) literature, and in particular the Event Calculus theory, to identify

the logical components of narratives (e.g. events, actions, fluents, physical object, agents), and give their formal definitions. Then, we studied the semantic models reported in the above Sections and we decided to map the identified logic components of narratives with the terms of two of the analyzed ontologies, the CIDOC CRM and DOLCE+, in order to evaluate if it would be possible to take one of them as reference vocabulary. We chose these ontologies since the first one is an ISO standard and the second one is a standard *de facto*. The above analysis shows that both DOLCE+ and the CRM are adequate to express the components of narratives. However, our choice has fallen on the CRM for the following main reasons:

- The CRM is an ISO standard since 2006 (ISO21127:2006) and renewed 2014 (ISO21127:2014). As such, it is widely known, it is regularly revised, and it is universally accessible.
- The CRM is specifically thought for the cultural heritage domain, and as such it is closer to the domain of narratives than DOLCE+. In fact, the CRM has been harmonized with the FRBR ontology (named as FRBRoo), a core ontology for bibliographic information, and therefore it provides fundamental notions to model text. Indeed, in many cases a narration represents a story expressed through a text.
- The Special Interest Group of the CRM continuously works for expanding the domain of applicability of the ontology, and a number of extensions have already been devised.

In order to define the factual components of the events, in particular we took into account the definitions reported in the LODE and SEM ontologies, where the main and necessary aspects that characterize an event are presented. A first version of the ontology, with descriptions of the classes and relations we used, is available online⁹.

For the development of the tool to build narratives, we have taken into consideration several past projects. For instance, the PATHS projects has been a model for the integration of digital objects in a narrative. Unlike PATHS, our model of narratives revolves around events, but we are also interested in linking events to the objects found in digital libraries. PATHS has also given us ideas about the interface for the narrative construction, in particular by providing a feature to construct narratives through a simple drag-and-drop functionality. During the development of the visualization components of our tool, the “thematic perspectives” on the knowledge base provided by the CultureSampo project have been a useful inspiration. However, we also had to analyze the requirements of the users in order to identify the specific visualizations which were necessary to them, and adapt each view to these requirements. A first version of the tool is available online¹⁰.

⁹ <http://narra.isti.cnr.it/ontology>.

¹⁰ <http://narra.isti.cnr.it/tool.html>.

5 Conclusions and Future Work

In this paper we have reported an overview of the main ontologies for representing events and of the tools developed in the Semantic Web field in order to visualize events and narratives. This overview has been useful for achieving the main goal of our research, that is the development of an ontology for representing narratives and, on the top of this ontology, a tool to construct narratives using the digital objects included in digital libraries. In this context, we intend narratives as semantic networks of events linked to each other and to digital objects by semantic relations. In particular, for developing an ontology for narratives, we have taken the CIDOC CRM as reference ontology and for defining the factual aspects of events we have referred to the LODE and SEM ontologies. For the development of the tool to construct narratives we took into consideration several existing projects, including PATHS and CultureSampo.

The long-term goal of our study is introducing the narrative as new first-class search functionality of digital libraries. As output of a query, this new search functionality should not only return a list of objects, as the current digital libraries do, but it should also present one or more narratives on the topic of the search.

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