SemanticHPST: Applying Semantic Web Principles and Technologies to the History and Philosophy of Science and Technology

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Abstract SemanticHPST is a project in which interacts ICT (especially Semantic Web) with history and philosophy of science and technology (HPST). Main difficulties in HPST are the large diversity of sources and points of view and a large volume of data. So, HPST scholars need to use new tools devoted to digital humanities based on semantic web. To ensure a certain level of genericity, this project is initially based on three sub-projects: the first one to the port-arsenal of Brest, the second one is dedicated to the correspondence of Henri Poincaré and the third one to the concept of energy. The aim of this paper is to present the project, its issues and goals and the first results and objectives in the field of harvesting distributed corpora, in advanced search in HPST corpora. Finally, we want to point out some issues about epistemological aspects about this project.

Keywords: HPST (history and philosophy of science and technology), modern history, Semantic web, RDFS annotations, HPST ontologies, exact search, approximate search, harvesting distributed corpora, epistemology

1 Introduction

The application of computer science to research in history has existed for a long time [1],[2] though it can be noticed that the recent research domain of "Digital Humanities" (DH) is growing as result of a digital "revolution" at work that impacts the whole society at the international level. In France, tools and utilities dedicated to DH like the very large facility Huma-Num (http://www.huma-num.fr) have been created in order to favor "the coordination of the collective production of corpora of sources (scientific recommendations, technological best

practices)." It also provides research teams in the human and social sciences with a range of utilities to facilitate the processing, access, storage and interoperability of various types of digital data." The *Dacos and Mounier report* [3] shows that the French research is active, however the authors recommend the creation of "Centers of Digital Humanities". The research network SemanticHPST is based on a strong coupling of laboratories in History and Philosophy of Science and Technology (HPST) and in Computer Science (LHSP–AHP, LORIA in Nancy) and (CFV, LabSTIIC in Brest) with research questions about the use of semantic web for HPST. The SemanticHPST project takes part in the emerging issues at the French and international levels in the domain of HPST.[1] Actually, the Semantic Web technology appears as efficient in order to generate tools adapted to the need of production and diffusion of distributed "intelligent digital" corpus in history [4].The objectives of the project are: (i) to integrate the existing technologies to manipulate digital contents of large volume by modeling knowledge as ontologies (annotation, request) for History and Philosophy of Science and Technology; (ii) to extent these technologies. The goal of this paper is to present the SemanticHPST project: its history, its objectives, the first results according to the information retrieval aspect and some epistemological issues. Because the methods in History of science and Technology are covering some elements of others domains in humanities (for example in history or in archeology), another goal of the SemanticHPST group is to share questions and results with the scientific community.

The paper is organized as follows. Section 2 presents the main goals of the SemanticHPST project and its three French HPST sub-projects for which semantic web technologies are useful. Section 3 presents some requirements and corresponding tools supporting different resource retrieval processes according to the researchers' practices. Section 4 presents some issues from an epistemological viewpoint. Section 5 concludes the paper.

2 The SemanticHPST Project

In November 2010, the main topic of a European workshop was the uses of ICT and history of science and technology in education.[2] To improve research in HPST on one hand, and to promote dissemination of the HPST in the field of education on the other hand, some participants were convinced by the necessity to use new ICT tools [6], [7], [8], [9].

[1] See the 18^{th} session organised by some authors of this paper during the last meeting of SFHST (French society for history of science and technology), April 2014 (http://sfhst2014lyon.sciencesconf.org/resource/page/id/5), and the last meeting of the international consortium DigitalHPS at Nancy, September 2014, (http://dhps2014.sciencesconf.org).

[2] After this workshop, an extensive book written by participants and others has been published in 2012 [5].

In 2012, some historians of science and technology and computer scientists have created a consortium called SemanticHPST.[3]

The main goal of SemanticHPST project is to enrich the practices of researchers and communities in HPST. According to the specificity of the practice as historians of science, three main issues were tackled:

1. The management of large quantities of data especially for the most recent periods (XIXth, XXth centuries up to the present day). Knowing that the historical approach involves to integrate relevant elements from the context of production of these data into metadata.
2. The heterogeneity of sources and corpora constituted from these sources.
3. The production of new relevant digital corpora from several available digital historical collections.

To address our main goal and the three previous issues, our project is based on the Semantic Web principles and technologies. Thus, it has three main sub-goals: (i) Building intelligent digital corpora, that is to say corpora with primary and secondary sources having semantic metadata and their corresponding ontologies; (ii) Designing tools to access and enrich existing corpora and to create new ones; (iii) Evaluating the resulting practices and building an epistemological viewpoint about the use of TIC in HPST.

To achieve these goals, it is necessary to ensure a certain level of genericity for metadata, ontology, computer-based tools and practices.

To deal with genericity and the diversity of sources, the project is applied in three different use cases or sub-projects with the aim to cover different methods and approaches that are typical in the domain of HPST. Those approaches are covering only partially the methods used in history and archaeology. These sub-projects are described in the following paragraph.

2.1 The port-arsenal of Brest

This sub-project takes part in the research programs "History of marine science and technology" and "Digital Humanities for History of Science and Technology" developed in Brest in the Centre F. Viète. One topic concerns the comprehension of the scientific and technological evolution of the port-arsenal in Brest (France) on a large period (XVIIth to XXth century) with a methodological approach considering this military-industrial complex dedicated to shipbuilding as a large technological system [10]. The objectives are:

1. To compose and publish a digital library (based on semantic web) about the material culture of the port-arsenal of Brest associated to several projects

[3] Participants at this consortium came initially from LaB-STICC (Telecom Bretagne, Brest), Centre François Viète (University of Brest), LIRDEF (University of Montpellier), LHSP-Archives Poincaré (University of Lorraine, Nancy) and later LORIA (University of Lorraine, Nancy). During the years 2012-2014, the INSHS (a French national institute of human and social sciences), the national network of Maisons des Sciences de l'Homme and University of Lorraine supported this consortium.

about 3D replications of artifacts and to cultural mediations dedicated to science and technology heritage.
2. To develop digital tools (based on semantic web) dedicated to a comparative history of science and technology of the port on a large area and a large period (since ancient times until now).

The hypothesis is to consider the large technological system of the port-arsenal as a large spatiotemporal and multi-scale artifact which is possible to decompose in elements of smaller scale (which are also artifacts) like industrial workshops, shipbuilding areas, storage areas, etc. Each of these elements are themselves composed by elements/artifact of smaller scale. The system has to be seen as the sum of all these artifacts and of all the relationships between them. The research in Brest [11], [12] has shown the interest to propose an historical evolution model of the port (inspired by works in geography [13]) where "simple" artifact like cranes, quays, dry docks are efficient indicators to characterize the cycle of evolution of the port-arsenal during a large period. This method is used in a comparative research [14] between Brest (France) and Mar del Plata (Argentine) in a thesis in progress by B. Rohou (directed by S. Garlatti and S. Laubé).[4] From these works, the contribution in the SemanticHPST group is to produce a methodology and a knowledge model efficient to produce a generic ontology where an artifact is a material object (made by human beings) associated to a "life cycle" with at least three steps:

1 design and construction of the artifact;
2 the artifact in use;
3 the disappearance of the artifact.

That "life cycle" involves the elaboration of fives categories of entities: time entities, actors (individuals or social groups), concepts/theories, location and artifacts. The analysis of the important ontology in the domain of cultural heritage named CIDOC-CRM (that "provides definitions and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation")[5] shows that this ontology could be a first reference to help and build our own ontologies because some concepts and relationships about "temporal entities" and "actors" can be reused. But if the concept of "Thing" exists in the CIDOC-CRM, we consider that the concept of "Artifact" and the associated relationships have to be elaborated first from our historical model and by considering of course the possibility of equivalent concepts in the CIDOC-CRM. A work is in progress in Brest about this topic from concrete examples of artifact as crane, quays and seawalls. A second step will be to examine others methods to produce ontologies well-adapted to our HPST problems in the domain of marine history [15].

This work is coupled with examples of typical requests (when and where were positioned all the cranes in the port of Brest since 1650 until 1970? In the

[4] See http://brmdp.hypotheses.org/.
[5] http://www.cidoc-crm.org/.

port of Mar del Plata? Which firms were in charge of the construction of the quays/cranes in the port of Brest since 1800 until 1900? What are the engine power of all cranes in the world since 1850 until 1970? Etc.).

2.2 Henri Poincaré's correspondence

The platform Henri Poincaré papers. In 1992, the laboratory of history of science and philosophy Archives Henri Poincaré was created to promote Henri Poincaré's manuscripts and to publish his correspondence. For more than 20 years, this long-term project has produced three volumes of letters: the first one is devoted to the Poincaré - Mittag-Leffler letters [16], the second one is on the correspondence with physicists, chemists and engineers [17], the third one is with astronomers and, in particular, geodesists [18]. Two other volumes are in preparation, one devoted to the letters from or of mathematicians and the other one consists of administrative and personnal correspondences.[6]

The corpus consists of more than 2000 letters, 1046 sent by Henri Poincaré and 949 received by him.[7] All known letters are digitalized[8] and around 50% of them are in plain text (in LaTeX and XML versions). Lots of letters contain mathematical and physical formulae. In Henri Poincaré Papers website,[9] the correspondence is available. In this platform, each known letter is indexed with Dublin Core extended metadata.[10] This enables to query the corpus by e.g.

Q_1 = "Letters sent by Henri Poincaré in 1885"
Q_2 = "Letters received by Eugénie Launois between 1882 and 1894"

There is also the possibility of plain text search for the letters already transcribed.

Towards more HPST-adapted search. Now, consider the following queries:

Q_3 = "Letters from an astronomer"
Q_4 = "Letters in reply to a letter of Mittag-Leffler"
Q_5 = "Letters about the n-body problem"
Q_6 = "Letters of the late XIXth century"

These queries cannot be executed in the current platform. They require additional data and knowledge:

[6] This correspondence is partly online http://henripoincarepapers.univ-lorraine.fr.
[7] About 50% of this letters are with scientists. Original letters come from 63 different archive centers and libraries from 14 countries.
[8] Due to copyright laws, some are not available online.
[9] http://henripoincarepapers.univ-lorraine.fr.
[10] It exists different projects devoted to scientific correspondences for example the CKCC project (http://ckcc.huygens.knaw.nl) [19] or Mapping the Republic of Letters (http://republicofletters.stanford.edu).

- Q_3 requires to know that an individual is an astronomer, possibly using deduction (for instance, Rodolphe Radau was a geodesist and every geodesist is an astronomer).
- Q_4 requires to know relationships between letters (including lost letters).
- Q_5 requires semantic annotations about the content of the letters (Poincaré worked on the three-boby problem).
- Q_6 raises the problem of modeling "late XIXth century": the boundaries of interval of time are imprecise.

The possibility to take into account such queries using semantic web principles and technologies, are examined in the SemanticHPST consortium.

2.3 The concept of energy

One part of the SemanticHPST project is dedicated to the concept of energy. Our aim is to create an ontology of energy for researchers working in the field of HPST as well as for science teachers.

For researchers, the ontology aims at making available a methodical body of knowledge that allows previously unseen connections to be made. For example, correspondence between two authors or the presence of a specific term or concept in a text will allow researchers to put forward hypotheses regarding the emergence of an idea or the cross-fertilization of ideas.

For teachers, the ontology aims at acting as a resource, allowing educators to find historical information relevant to school curricula as well as ideas for specific activities to carry out in the classroom.

The content consists of reference texts in the field of HPST, contemporary scientific texts and a database of historic scientific instruments and documents. This content is currently being selected and developed and will be enhanced as the research progresses.

To date, the following three steps have been undertaken on the project:

- The first step was to identify the presumed ways the ontology will be used, for example, the type of requests that a researcher or teacher might make in a search. To this end, one 'persona' for a researcher and one for a teacher have been created. Analyzing the theoretical queries from these two personas helps in the selection of a relevant body of work and is also a useful guide for indexing.
- The second step was to begin indexing the reference texts. Duhem, Poincaré, Mach and Meyerson have been selected for a first approach in order to produce keywords and common references and to outline an embryonic model. Using the shared scientific knowledge of the physicists involved in the project, a sort of 'cloud' of concepts related to describing energy was defined and classified. These elements led to the structure of an initial mind map.
- Finally, based on this mind map (created with Docear), we used Protégé software to create a first draft overview of the project. The next steps require documenting these three steps in detail to refine the data and then build the ontology.

During the stages of the project carried out so far, various problems have been identified that must be resolved. One of the main problems concerns the modeling of time. How can an event be modeled? Moreover, how can knowledge be modeled in a way that avoids immobilizing the knowledge? How should knowledge be contextualized? What approach should be adopted when modeling concerns a concept or an object? How can a coherent and logical body of content be created and how can its coherence be assessed? It is clear that the question of time as well as how to approach the treatment of objects and works are issues to be investigated in the semanticHPST project.

3 The SemanticHPST tools and requirements

According to the three described sub-projects, the main goals of researchers in HPST are to access and retrieve relevant resources in existing primary and secondary sources or corpora, to produce new resources in existing corpora, to enrich existing digital corpora or to create new ones, for answering research questions in the history of science and technology. Existing digital corpora come from libraries, information holdings, digital libraries or others like Gallica (http://gallica.bnf.fr), Internet Archive (http://archive.org), Google Books (http://books.google.com), etc., and CMS (Content Management System) (blogs, wikis, Drupal, Omeka, etc. more generally social media tools) have been used by the community[11] and digital AHP (http://www.ahp-numerique.fr/). Some heritage and bibliographic resources have already been described by several institutions, associations and/or project (BNF, Gallica, British Museum, Europeana, Amsterdam Museum, LODLAM, ...). The creation of new corpora or resources can be made on social media tools distributed on Internet (as well as other digital corpora).

The design of tools for HPST researchers has to integrate and/or aggregate the existing heterogeneous tools and to ensure interoperability among them. Thus, the goal is not to build a single new environment, but to design a platform which integrates existing tools selected for their relevance according to the practices of researchers and provide an agile architecture able to model and/or support the processes involved in the research work and enrichment.

This platform will be mainly based on the Semantic Web and Linked Data approaches (RDF Triple Store, ontologies, OWL 2, RDFS, SPARQL, etc.). Nevertheless, the platform will also provide access to non-semantic resources. A network of ontologies dedicated to HPST will be designed to meet the interoperability and open access requirements for corpora. Some existing ontologies and standards will be reused and integrated in the ontology network, like CIDOC-CRM, FRBRoo, FRSAD, Dublin Core, etc. and those available at LOV (http://lov.okfn.org/dataset/lov/).

In this paper, we focus our attention on the resource retrieval problem that we can divide into two different aspects : advanced search in HPST corpora and harvesting distributed corpora. The former focuses on advanced search function-

[11] The *alambic numérique* (http://alambic.hypotheses.org/4924) is based on Omeka.

alities in a single corpus. The latter studies the resource retrieval on distributed corpora. These two aspects will be integrated.

3.1 Advanced search in HPST corpora

In order to perform advanced searches in a HPST corpus, we have to build intelligent digital corpus: corpus with primary and secondary sources having semantic metadata (RDF Triples) and their corresponding ontologies using a fragment of OWL (actually, RDFS will be sufficient for the following examples). These ontologies are domain ontologies related to the corpus. A domain ontology for Henri Poincaré letters has already been designed. Finally, some tools will have to be developed for answering some of the queries.

This section presents the advanced search using the query examples Q_3-Q_6 introduced in Section 2.2.

Q_3 requires some additional data and knowledge to get satisfactory answers, as stated in Section 2.2. In particular, if the annotation file contains the following RDFS triples:

(`letter1 isSentBy rodolphe_radau`)

(`rodolphe_radau rdf:type Geodesist`)

(`Geodesist rdfs:subClassOf Astronomer`)

then the execution of the following SPARQL query on an engine supporting RDFS

$$Q_3 = \text{SELECT } ?\ell \text{ WHERE } \{?\ell \texttt{ isSentBy ?a . ?a rdf:type Astronomer}\}$$

will return `letter1`.

Q_4, similarly, can be answered by a SPARQL engine supporting RDFS with the following query:

$$Q_4 = \text{SELECT } ?\ell \text{ WHERE } \left\{ \begin{array}{l} ?\ell \texttt{ isAnAnswerTo } ?\ell 2 \texttt{ .} \\ ?\ell 2 \texttt{ isSentBy mittag-leffler} \end{array} \right\}$$

It can be noticed that this query can give a letter of the corpus that answers a lost letter: the missing letter cannot be found, but its answer can.

Q_5, for being executed, requires the use of annotations about the scientific content of the letter:

$$Q_5 = \text{SELECT } ?\ell \text{ WHERE } \left\{ \begin{array}{l} ?\ell \texttt{ hasForTopic ?t .} \\ \texttt{?t rdf:type N-body-problem} \end{array} \right\}$$

The n-body problem is a topic having sub-topics, in particular, the 3-body problem is a problem more specific than the n-body problem. For this reason, we have chosen to model these two problems by two classes, the former being more general than the latter. Therefore, a letter of the corpus about the 3-body problem will be returned by the execution of this query.[12]

[12] We could also have chosen to model the 3-body problem as an instance of the n-body problem, but first, it is more homogeneous to consider every topic as a class,

Q_6 can be modeled by a SPARQL query based on the assumption that "the late XIXth century" corresponds to the interval $1881 - 1900$:

$$Q_6 = \text{SELECT } ?\ell \text{ WHERE } \left\{ \begin{array}{l} ?\ell \texttt{ sentDuringYear ?y .} \\ \text{FILTER}(\texttt{?y >= } 1881 \texttt{ \&\& ?y <= } 1900) \end{array} \right\}$$

However, this solution is debatable: the modeling of the fuzzy period of time by a crisp interval raises the problem of the choice of the boundaries. Indeed, some events before 1881 or after 1900 can be considered by historians to be related to the end of the XIXth century. In order to address this issue, some approximate search is planned. How to put this idea in practice is an ongoing work.

3.2 Harvesting distributed corpora

Harvesting distributed corpora at semantic level (according to Linked Data principles) require to solve two different problems. The first one is to queries several triple store by means of federated queries to linked distributed sources. The second one is to get RDF triples from social media tools.

Most of social media applications are data silos. In other words, data are unavailable on the web. Only people may have access to data, not computers. Reuse and exchange of data among social media tools are only possible by means of API – that is to say manually by mean of one API per tool. Some social media tools like Drupal, Semantic media wiki may have their own triple store exposing data to others.

A toolkit, called SMOOPLE for Semantic Massive Open Online Pervasive Learning Environment, has been designed to solve these two problems. It was firstly dedicated to the technology-enhanced learning domain [20]. The core part of the toolkit can be reused for HPST. It fulfills the needs of researchers in HPST, that is to say it enables us to federate distributed sources and tools.

SMOOPLE has semantic services which are in charge of managing incorporated semantic models, extracting and storing the data produced on social media tools, making and answering to semantic queries against one or several distributed sources (federated queries). The Semantic Web server (semantic services) is based on Jena 2. When the social media tools do not have a triple store and a SPARQL endpoint, content and corresponding semantic metadata can be extracted on the fly from social media applications, by means of plugin (similar to sioc_export) and stored in a RDF repository. Several light ontologies (SIOC, FOAF, DC, RDF, RDFS, etc.) are used to acquire semantic metadata automatically. It will be necessary to define the interlinkage among distributed sources (triple stores) to support federated queries.

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second, this way, it is always possible to consider a more specific topic, e.g., the restricted 3-body problem for which the mass of one of the 3 bodies in considered to be negligible.

4 Epistemological aspects

An aim of the SemanticHPST project is to focus on the epistemological issues raised by the development of these new tools based on semantic web. This work in progress takes part to epistemological questions in the domain of Digital Humanities.[13] A first series of questions concerns the modeling of knowledge, the main step in building ontologies so that researchers can easily identify and apprehend knowledge. Therefore the creation of effective ontologies requires defining concepts and elucidating certain tacit or implicit knowledge. So the initial questions are: How to approach these definitions? How to ensure that indexing does not immobilize knowledge? How can the modeling anticipate how it will be used in order to ensure that the knowledge generated is contextualized to avoid anachronism and misinterpretation? Moreover, the wide range of works in the collection, including texts (manuscripts, books, letters, web pages), multimedia documents, 3D archaeological or historical objects and media from a variety of sources (photographs, original texts, maps, etc.), necessitate different approaches. This raises the question: How to approach a photograph, a scientific instrument or a text and still obtain a unified ontology? How can the modeling enable relationships between objects yet avoid the pitfalls described above?

In the field of HPST, the issue of modeling time is central and particularly tricky. Modeling a long period of time, an event, a succession of events or events that are juxtaposed requires making decisions that should be taken collectively. Indeed, this emerging issue is shared by historians [23], [24], [25] and should serve to feed into theoretical discussions between researchers from different disciplines.

A second series of questions concerns the researcher's environment, which has significantly changed with the rise of digitized data. Whatever the works considered or their origin (libraries, archives, etc.), the massive volume of data, its diversity and location are all part of this change. Yet this radical shift is not exclusively the result of the accumulation of a large amount of data. The fact that data can be 'analyzed as well as communicated, represented, reused – in short, mobilized for research – in a quantity and with an ease incomparable with previous periods' [3] is a major transformation that needs to be taken into account. This raises new questions for researchers:

- How does one build and define a body of content that is coherent and complete? Whereas 'traditional' methods created collections using identified, bounded, localized archives, with the question of consistency limited in most cases to the cross-fertilization of archives as regards the historical context, the accessibility of multiple documents today requires a reexamination of the very concept of a collection of works.
- How does one evaluate a body of work; in other words, how does one recognize its relevance?
- In this context, the type of source and its references must be specified. Does the wide range of sources used require more refined classification than the

[13] See thematical issue "la numérisation du patrimoine" of [21] or the issue "Le métier d'historien à l'ère numérique : nouveaux outils, nouvelle épistémologie ?" of [22].

standard usage of primary and secondary sources? Would a new typology be pertinent given this broad diversity? Should the references to these sources, particularly information concerning digital archives, lead to new codification that allows, for example, multiple identifications for the considered source, improving its accessibility?

5 Conclusion

The aim of this proposal is to contribute to the development of the research in the domain of digital humanities. Based on the Semantic Web principles and technologies, the SemanticHPST group proposes new methodologies in History and Philosophy of Science and Technology in the framework of a strong collaboration between labs working in the area of computer science and humanities (here HPST). The main goal is to enrich the practices of researcher and communities in HPST as well in science and technology heritage. To deal with such a goal, the project has to: i) Build intelligent digital corpora, that is to say corpora with primary and secondary sources having semantic metadata and their corresponding ontologies; ii) Design tools to access and enrich existing corpora and to create new ones; iii) Evaluate the resulting evolution of practices in historical science and build an epistemological viewpoint about the impact of new tools and practices in humanities based on knowledge modeling and semantic web.

Another important issue is to deal with the reuse of intelligent digital corpora. Thus, it is necessary to build representations of the entities, people and processes involved in producing the digital corpora. The "PROV Model Primer" from W3C (http://www.w3.org/TR/prov-primer/) can be used to address this issue.

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