Kolflow: co-evolution of content and knowledge

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1 Introduction

Web 2.0 is currently producing a huge amount of information. Continuously transforming this information into knowledge is a major challenge for the research community. Automated reasoning or collective intelligence are currently two representative approaches to transform content into knowledge. The *Kolflow project proposes to extend collective intelligence with smart agents relying on automated reasoning.* Smart agents can significantly reduce the overhead of communities in the process of continuously building knowledge. Consequently, continuous knowledge building is much more efficient.

Kolflow aims at building a social semantic space where humans collaborate with smart agents in order to produce knowledge understandable by humans and machines. Humans are able to understand the actions of smart agents. Smart agents are able to understand actions of humans. Kolflow targets the co-evolution of content and knowledge as the result of interactions of humans and machines.

If human-machine collaboration can be the key to ensure co-evolution of content and knowledge, such collaboration can fail if not managed. The Kolflow project addresses the following scientific issues:

Man-machine collaboration: Man-machine collaboration can be very unstable and make the whole system divergent. How to coordinate the actions

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of distributed agents, either software or humans, sharing web contents and knowledge accessed by web users at a potentially large scale? In particular, a key issue is to guarantee a minimal stability and the non-regression of the whole system.

Man-machine collaboration for humans: how to make formal knowledge and its evolution accessible, usable, editable and understandable by human agents so they can observe, control, evaluate and reuse the outputs of smart agents?

Man-machine collaboration for machines: how to support and take into account the unpredictable behavior of human agents that can at any moment add or modify content and formal knowledge with the risk of introducing uncertainty or inconsistency? How automated reasonings can adapt their behavior and results by taking into account feedback from human agents? How these tools can adapt their behavior and results to specific user needs in a given context?

Kolflow produced several major contributions: i) Kolflow proposed two main use-cases. Section 2 presents results on co-evolution of wikipedia and dbpedia. Section 3 presents how Taaable system[1] can be seen a social semantic space. ii) Section 4 details results obtained on traces and explanations. iii) Section 5 presents results obtained on revising ontologies iv) Section 6 details results obtained on makeing linked data writable v) Section 7 presents results obtained on continuous extraction

Finally, we conclude and point out perspectives.

2 From DBPedia to Wikipedia

We can consider that Wikipedia and DBPedia partially implement a social semantic space. DBpedia [5] knowledge base is built from data extracted from Wikipedia infoboxes and categories. The semantic capacities of DBpedia enable SPARQL [35] queries to retrieve information that is not present in Wikipedia [44]. For instance, it is possible to make a query over DBpedia to find *"everyone in Wikipedia that born in Boston"*. This query produces a set of couples *(Boston, Person Name)* which are related by the semantic property of DBpedia *"is birth place of"*. Surprisingly, the list of people retrieved by the previous query could include more people than those obtained by navigating from Boston[2] article in Wikipedia. This shows that some information existing in DBpedia is missing in Wikipedia and more generally problems of co-evolution of content and knowledge. However, adding these missing links to Wikipedia is not an easy task since it is necessary to respect Wikipedia conventions[3]. This raise the problem

[1] htttp://taaable.fr
[2] In the scope of this article we will use Boston instead of Boston, Massachusetts
[3] `http://en.wikipedia.org/wiki/Wikipedia:Conventions`

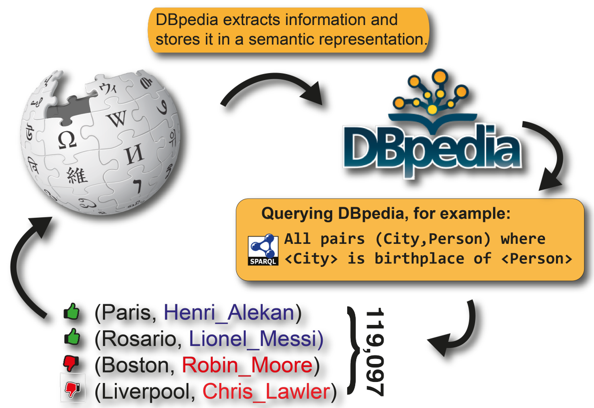

Figure 1: From DBPedia to Wikipedia

of extracting information from semantic web to improve web of document and closing the loop of a social semantic space as illustrated in figure 1.

We introduced the BlueFinder algorithm that is able recommend better representation for a DBpedia semantic property in Wikipedia. BlueFinder pays special attention to the specificity of the resource types in DBpedia. It follows a collaborative filtering approach [29] to recommend a relation between a given couple of Wikipedia pages and a given semantic property.

Results [46, 45, 11, 43] demonstrate that it is now possible to add automatically with high confidence more 120 000 missing links in wikipedia and reduce the information gap between Wikipedia and DbPedia.

3 Co-evolution in Taaable System

During the project, we have massively used the Taaable application to conduct experiments and implement knowledge co-evolution processes. Taaable is a web-based environment performing semi-automatic retrieval and adaptation of cooking recipes following a case-based reasoning approach. It is a perfect environment to experiment with knowledge co-evolution issues as it is a rich and evloving environment, and it is very easy to understand for end users.

In Taaable, knowledge necessary for the representation of recipes and for their adaptation is stored in a semantic wiki accessible by all and editable by sufficiently experienced users. We used this project as a test-bed to implement and experiment our strategies and mechanisms of continuous evolution of knowledge.

We first instrumented the environment to allow the collection of interaction traces (traces produced by the edition of semantic wiki pages), and then we defined mechanisms of assistance based on the exploitation of these interaction traces. The objective here was to facilitate the appropriation of the tool by novice users and to support the sharing of experiences between users of the platform [31]. This contribution was also important becauses it set the basis for trace collection in distributed environments such as distributed semantic wikis.

Then, based on this first work, we proposed K-CIP [40], a process drawing inspiration from continuous integration for evolution of knowledge. K-CIP stands for Knowledge Continuous Integration Process. K-CIP consists in harvesting the feedback of users on specific queries to semi-automatically build tests than can be further reused to control the evolution of knowledge.

In [10], we demonstrated how to use these approches to acquire a specific type of knowledge: adaptation knowledge. We implemented examples within the Taaable environment.

4 Traces and Explanations

In this section, we aim at assisting users in understanding query behavior and results in the context of consuming Linked Data. We have contributions in five areas: query performance prediction, query result provenance, evaluating explanations, explanation for Linked Data, and summarizing explanations for Linked Data.

Query Performance Prediction. Existing approaches for SPARQL query cost estimation are based on statistics about the underlying data. However, statistics about the underlying data are often missing in Linked Data. We proposed a machine learning approach to predict query performance metrics [24, 19, 25]. We learn query execution times from already executed queries – without using statistics about the underlying RDF data. We modeled SPARQL queries as feature vectors to provide accurate predictions. Predicted query performance metrics using our approach can be used to assist users to understand query performance for workload management related tasks to meet specific QoS targets in the context of querying Linked Data.

Query Result Provence. Previous works on generating why-provenance for SPARQL query results are based on what is known as the annotation approach (or eager approach) where the underlying data model, the query language, and the query processing engine are re-engineered to compute provenance during the query processing [21]. However, re-engineering the underlying data model, the query language, or the query processor is often not possible in the Linked Data scenario. We proposed a non-annotation approach to generate why-provenance for SPARQL query results and show its feasibility for common Linked Data queries. We generate the explanation for a SPARQL query result tuple from its why-provenance. We tested it on an explanation-aware federated query processor prototype and showed the generation of explanations in that context.

Evaluating Explanations. Previous works on explanations in the Semantic Web literature work on the assumptions that explanations would improve users' understanding and trust. However, previous works do not evaluate such assumptions. We carried out a user study to evaluate the impact of query result explanations in a federated query processing scenario for Linked Data [20]. Our user study shows that our query result explanations are helpful for end users to understand the result derivations and make trust judgments on the results.

Explanations for Linked Data. Much of the previous work on explanations for the Semantic Web do not address explanation in a distributed environment. We propose a decentralized solution to this problem. We showed how to represent and generate explanations for Linked Data and designed the Ratio4TA vocabulary to describe explanation metadata and introduce the notion of Linked Explanations – publishing explanation metadata as Linked Data. This enables explaining distributed data in a decentralized fashion. Ratio4TA extends the W3C PROV Ontology to enable data consumers to process explanation metadata according to W3C PROV standards. We also showed how to generate natural language based explanations from these explanation metadata.[22]

Summarizing Explanations for Linked Data. Although explanations with the details of all the derivation steps may be useful for expert users, they may overwhelm non-expert users with too much information. In addition, an expert user such as a knowledge engineer may want to focus on a specific part of a detailed explanation. A knowledge engineer may also want a short explanation to have an overview of the reasoning. We compared five measures to summarize explanations and evaluated different combinations of these measures. The evaluation shows that our approach produces high quality rankings for summarizing explanation statements. Our summarized explanations are highly accurate with F-score values ranging from 0.6 to 0.72 for small summaries. Our approach outperforms the sentence graph based ontology summarization approach. [18, 23]

5 Dealing with semantic inconsistencies

The task 3 of Kolflow deals with the issue of merging two knowledge bases (e.g., two ontologies). This is known as the issue of belief change, which includes belief revision, that is explained hereafter.

Let us consider an agent with a set of beliefs ψ about the world. This agent is confronted to a new set of beliefs μ, that he/she considers to be more reliable than its original beliefs ψ. The question is what is the new set of beliefs $\psi \dotplus \mu$ of the agent. The principle of minimal change asserts that the answer is the conjuction $\psi' \wedge \mu$ where ψ' is obtained by "the minimal change" of ψ such that this conjunction is consistent.

Theoretical issues related to this issue has been developped for decades, but the development of operational systems implementing revision operators $\dotplus$ is much more recent. Some such operators have been developped and gathered as a library called Revisor [7, 8] (`http://revisor.loria.fr`) and including several parts:

- Revisor/PL and Revisor/PLAK deal with revision in a propositional formalism, for the former, minimal change is measured by a weighted Hamming distance between interpretations whereas the latter uses adaptation rules [37, 36];

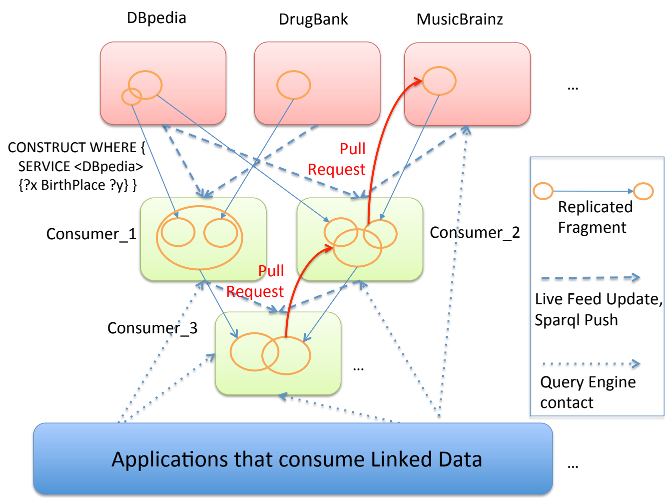

Figure 2: Federation of Writable Linked Data

- Revisor/CLC works in the formalism of conjunction of linear constraints [8], using a city-block distance between interpretations (an interpretation being an element of $\mathbb{R}^n$);
- Revisor/QA works in the formalism of qualitative algebras [15] and has been extended to Revisor/PCQA, working in the formalism of propositional closures of qualitative algebras [13, 14] (the algebras implemented are Allen algebra, INDU and RCC8);
- Revisor/RDFS works in RDFS. A publication about this system is under writing. However, a first paper on the related issue of belief merging of taxonomies has already been published [9].

6 Social Semantic Spaces

The Linked Open Data initiative (LOD) makes millions of RDF-triples available for querying through a federation of SPARQL endpoints. However, the LOD faces major challenges including quality of data [1].

These issues are observed by data consumers when they perform federated queries; results can be wrong or out-of-date. If a data consumer finds a mistake, how can she fix it? This raises the issue of the *writability* of Linked Data, as already pointed out by T. Berners-Lee [4]. Making linked data writable is the necessary condition to build a social semantic space.

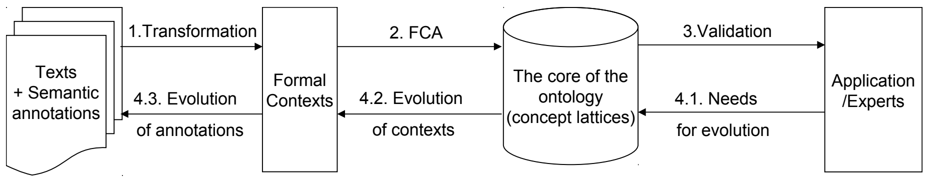

Figure 3: The general process of our continuous knowledge system.

We devise an extension of Linked Data with data replicated by Linked Data consumers. Consumers can perform intensive querying and improve data quality on their local replicas. We call replicated subsets of data, *fragments*. As illustrated in figure 2, any participant creates fragments from different data providers and make them available to others through a regular SPARQL Endpoint. Local fragments are writable, allowing modifications to enhance data quality. Original data providers can be contacted to consume local changes in the spirit of *pull requests* in Distributed Version Control Systems (DVCS). Second, the union of local fragments creates an opportunistic replication scheme that can be used by federated query engines to improve data availability [32, 38]. Finally, update propagation between fragments is powered by live feeds as in DBpedia Live [33] or sparqlPuSH [34].

Scientific issues arise concerning the consistency of these fragments. These questions have been extensively studied in Collaborative Data Sharing Systems (CDSS) [30], Linked Data with adaptations of DVCS [39, 6] and replication techniques [27, 47]. Existing approaches follow a total replication approach, *i.e.*, full datasets or their full histories are completely replicated at each participant or they require coordination to maintain consistency.

In Kolflow, we proposed Col-Graph and Live Linked Data [28, 26] , a new approach to solve the availability, scalability and writability problems of Linked Data. In Col-Graph, we defined fragments as SPARQL CONSTRUCT federated queries, creating a *collaboration network*, propose a consistency criterion and define a coordination-free protocol to maintain fragments incrementally without reevaluating the query on the data source. The protocol counts the derivations of triples for data synchronization and keeps provenance information to make decisions in case of a conflict.

7 Continuous extraction

We developed a continuous system for knowledge extraction from texts based on Formal Concept Analysis (FCA) ([16]). The system is continuous as it keeps the link between each knowledge nuggets and its linguistic expressions in texts (semantic annotations) and any change in annotations (new annotation, new text, removing annotation) may result in a change in the conceptualisation of the domain. Moreover, in the opposite way, any interaction on the knowledge model results in changes in text annotations.

Building an ontology from texts is a complex [2, 41], time-consuming and costly task. It involves such steps as collecting resources, preprocessing and processing these resources to switch progressively from the linguistic level (words, terms...) to the conceptual level. Domain expert guides this iterative process by favoring the emergence of certain words, concepts, or by introducing nuggets of knowledge which are missing. His role is essential, making use of his own knowledge, but also taking into account the task for which the ontology is built. He is never sure to take the right decision, and several reasons may motivate changes or improvements in an ontology: (1) the knowledge modeled in the ontology is not in accordance with expert knowledge; (2) the task or application using the ontology does not produce the expected results; (3) new resources, including new texts, are taken into account.

Our continuous knowledge extraction system [42] is based on FCA, a symbolic classification method and a powerful tool for conceptualisation. The lattice can be transformed into a knowledge representation formalism such as Description Logics, a formalism widely used to encode ontologies. Some explicit knowledge can be manually introduced to overcome the implicit knowledge contained in the texts as suggested in [3]. We will also benefit from incremental algorithms that have been implemented to build lattices ([17]) not only to avoid complete recalculation of the lattice but also for identifying the different possible strategies to perform a given change in the current conceptualisation. Figure 3 gives the general schema of our system.

8 Conclusions and Perspectives

Kolflow pointed out necessary co-evolution of contents and knowledge and described how such process can be enabled.

First, we emphasized the need for a writable semantic web in order to enable continuous knowledge improvement. When querying knowledge, If users can see mistakes, they need to be able to fix it. This problem is challenging in a federation with autonomous participants as in linked data. Main results are presented with Lived Linked Data and Col-Graph approaches [28, 26]. Second, understanding results of queries or the presence of a fact are fundamental to interact with semantic web. Kolflow produced results on explanations with usage studies proving explanation impacts [21, 18, 22]. Third, transforming user feedback into knowledge is a key issue for knowledge evolution. In Kolflow, we demonstrated how it is possible to extract data quality assertions from user feedback and consequently manage knowledge evolution. This has been mainly experimented in the Taaable system [31, 40, 10]. We also addressed the problem of knowledge evolution with revision operators that are able to propose to users different consistent evolutions [9, 12]. Finally, we addressed the problem of how knowledge evolution can be pushed back on original contents. We demonstrated how DBPedia relations can be pushed back to Wikipedia respecting Wikipedia convention with BlueFinder [46, 45, 11, 43]. We also demonstrated how operations on ontologies lattices can be pushed back on content annotations stored in a semantic wiki [42].

Kolflow investigated many issues of man-machine collaboration; extracting knowledge from annotations, extracting knowledge from interactions, extracting content from knowledge, explaining, constraining knowledge evolution, crowdsourcing changes. All these aspects are crucial for a fruitful co-evolution of content and knowledge. Kolflow demonstrated that such co-evolution is mainly dependent of how man-machine collaboration is managed and exploited.

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