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PROTOTYPICAL IMPLEMENTATION OF A DECENTRALIZED SEMANTIC-WEB-BASED INFORMATION SYSTEM FOR SPECIFIC STUDY PROGRAMS

Summary: The paper describes the approach and the results of an agile student's development project. Initial point was the idea of a decentralized guide for specific study programs located in the DACH (Germany, Austria, Switzerland) region. Compared with existing systems, this guide is meant to provide relevant, and moreover commensurable information about the subject-specifics features of study programs. Prospective students ought to get support in their study decision. In addition, the system may support other stakeholders, e. g. companies searching for qualified personnel in a specific field. The basic idea is to allow the semantic enrichment of any website of a university on study programs (i.e. in a decentralized manner), which is based on an ontology for Information Systems study programs. Doing so, this information become web-wide accessible and may be aggregated and visualized in a web application. The single stages of development will be described from a business as well as from a technical perspective.

Keywords: education management, semantic web application, knowledge extraction, semantic annotation.

1. Motivation and structure of the paper

Nowadays, information about study programs are accessible for everyone by a very few clicks. Each university describes each study program on its website, mostly within university-wide implemented content management systems (CMS) which allow responsive display of its content with respect to the terminal equipment. In addition, there is a multitude of information portals which collect or gather that data and process it in a user-friendly way (cf. [1]). These portals

are widely used by the universities to advertise their study programs. They are interested to attract "the right" students. A focal point in such decisions may be the subject-specific features in a study program and – as an implication of this – the potential future occupational areas. This kind of information is hard to extract from university websites or from information portals. It is even harder to compare them to each other. It is a relevant task to establish such kind of comparability – here prototypically for study programs in Information Systems at Universities of Applied Sciences (UAS).

Technically necessary are uniformly structured data, as they are successfully offered today by large information portals and search engines for persons and objects of the public interest. For example, important data about countries in the Wikipedia are uniformly collected and displayed in the form of a table, whereas when searching for movie actors in Google photos, biographical data, roles, etc. are delivered, also in a recognizable structure. The underlying technologies are mostly associated with knowledge graphs. A study guide which collects and process the locally stored information in a standardized way needs a conceptual schema, i.e. a knowledge graph for study programs. In analogy to Google's Knowledge Graph, this approach should be called EduGraph. The ontology developed for this purpose and described in [1] was named after the English abbreviation of Business & Information Systems Engineering (BISE).

The paper concerns a prototypical development of a decentralized study guide with the mentioned characteristics. Section 2 shows related work and describes the applied methodologies. Section 3 is devoted to the systematic deduction of use cases with regard to typical IT operation structures and processes at universities. It is based on expert interviews as well as an interdisciplinary workshop. The stages of prototypical implementation, starting from an architectural model and the interaction of different components, are treated in Section 4. In each stage technological approaches have been explored, evaluated and adapted if necessary. The components implemented in the prototype include the technical foundations of annotation, the extraction of exemplary annotated data and their aggregation and visualization in a web application. The paper concludes with a summary and an outlook on further research issues and development challenges.

2. Related work and methodological approach

One of the most discussed topics in the Semantic Web (SW) research community is the contradiction between the well-founded great expectations of benefits derived from utilization of SW technologies in Web applications and the up

to now marginal degree of their implementation in real life Web applications [2]. Even worse, most of these implementations are concentrated in a small number of industries, like media, life sciences, tourism, and library sciences (e.g. [3], [4], [5], [6], [7]). The presented paper is a little attempt to close this gap regarding the education management domain. While there is a great variety of research concerned with SW technologies in the e-learning domain with the main focus on supporting the access to learning resources (cf. [8], [9], [10], [11]) very little investigations deal with organizational aspects of educational institutions ([12], [13], [14], [15]) and certainly not with standardized information supply across organizations.

The presented work coalesces an organizational and a technological approach to the development of a real life SW application and thereby addresses one of the serious shortfalls of other approaches, which focuses primarily on specific, mostly high-level SW technologies or even artificial intelligence challenges or which neglects the business evaluation of the developed solutions. Another serious problem is the gap between the ever accelerating progress in Web applications development and the genuine requirements of SW technologies (see [16], [17], [18], [19]). Regarding the technologies itself, the paper does not present innovations, but rather designs an adapted set of items taken from different technological fields, like SW standards (RDF, RDFS, SPARQL), SW vocabularies (schema.org), SW frameworks (Apache Jena, RDF Translator [20], Microdata, BASIL, grlc), and common Content Management Systems (TYPO3) – to name the most important.

The main research questions of the presented work are the following:

1. What are the relevant use cases in the application field?
2. Which kind of knowledge graph (or ontology) fits best for the application?
3. Which set of Web development and Semantic-Web technologies supports best the targeted application?

These kind of research questions are characteristic in the field of Design Science, like explained by Hevner et al. in [21]. Wilde and Hess performed in [22] an empirical study of applied scientific methods in Business & Information Systems Engineering, differentiating on the one hand the two paradigms: behavioral research versus engineering, and on the other hand the degree of formal rigor: qualitative versus quantitative research. The scientific methods in the presented work are taken from the portfolio investigated in [22]. Research question 1 is concerned with use cases in a given application field, i. e. methods shall be taken from the behavioral research. Since the main goal was a prototypical development and implementation in a dynamically changing application field an

expensive quantitative method does not fit. It is best practice to use the case study method, i. e. to choose a sample of objects of investigation as typical as possible and to use as individual as possible investigation tools. Expert interviews and workshops were used as main features for data collection. For elaborating the use cases a kind of clustering and projecting was used targeting at the same time on remaining the expert's wording as genuine as possible. The other two research questions belong to the engineering paradigm. Based on a thorough analysis of existing tools, models and frameworks the following research methods were applied: reference modeling for the ontology engineering (research question 2) and prototyping for research question 3. These engineering methods were applied in an agile manner, implementing aspects of rapid prototyping and continuous integration.

3. Use cases for the annotation of program websites

The basis for a decentralized study guide are semantically enriched program websites. Therefore, this is a critical success factor for the overall project. The current concept is dependent on semantic mark-up provided by the universities. A range of use cases were developed to design a convenient and easy-to-use solution for universities and program managers which represents a lowest possible hurdle and requires a reasonable effort. This development starts with a qualitative field research based on expert interviews with persons in charge at different universities and on an interdisciplinary workshop.

The interviews were initiated in October 2015. Managers from nationwide nine UAS with study programs in Information Systems were interviewed on the subject Semantic Web and information publishing at the Internet. The interdisciplinary workshop was conducted with marketing executives, editors for the content creation and maintenance as well as experts for CMS and Semantic Web technologies. The following findings regarding the conduct of development were collected:

- The sustainable acquisition of prospect students and an individual communication of information are central issues for universities. To be active through various channels, universities maintain their data manually in up to 50 portals and platforms.
- In most of the cases the means for editing in CMS templates are limited used for the display of study program websites. On the other hand, templates pro-

vide a basic structuring of data. Machine readable content structure or content tagging were not identified.

- Websites of study programs are edited unfrequently, mostly only before the start of a new semester.
- Most of the universities in Germany are using the CMS TYPO3. Therefor the further discussion will be restricted to TYPO3 systems and respective solutions.

The systematic analysis of the collected research data reveals the following use cases:

Use Case 1: Marketing and visibility in the internet (SEO)

There is a big number of information portals regarding study programs, so providing another one seems to be contradictious and moreover associated with additional effort for the users. But in fact, the system's architecture based on semantic annotation does not require extra data maintenance effort on external platforms. Moreover, semantic annotation facilitates the machine readability of page content and thereby becomes more and more an important factor in search engine optimization. Therefor it gives a positive side effect on visibility in the internet. So, presumably, content annotation will become a must in the future.

Use Case 2: Design-driven website relaunch

Since the CMS TYPO3 is widely distributed in the higher education sector in Germany website relaunch projects in the most of the cases does not question the usage of that system itself. The relaunch is rather oriented at design issues, mostly focused on the separation of content and design elements and, not at least, on responsible presentation of the content on different devices. By the way, a consolidation and optimization of content elements is triggered even in such projects. The revision of content structures and templates provides a perfect moment for enhancing the templates by semantic annotation.

Use case 3: Technology-driven template revisions

Due to technology enhancements and the dynamics in business requirements the need for new or additional functionality of the CMS can arise. It makes sense to enhance the content structure under consideration by semantic annotation. Template revisions for university CMS' are mostly realized by experienced agencies, since the universities itself does not have experienced enough personnel for tasks like this. Working with well qualified experts provides good chances to implement semantic annotation in the course of template rework.

Use case 4: No technical changes possible regarding the CMS

After a successful CMS relaunch, the probability for implementing additional enhancements or new technical configurations decreases substantially. Reasons for that may be technological considerations in the datacenter of the university. They are concerned with challenges like security, compatibility, interdependency, and performance with respect to each system update. In that constellation semantic annotations may come out to be complex and possibly not stable regarding future system updates.

To sum up, the lowest barriers for the implementation of semantic annotations can be detected in the course of current or planned website relaunch projects.

4. Prototypical implementation of the decentralized study guide

To distinguish the system described here from existing study guides, in this paper the term *decentralized* study guide is used. Main motivation to use such a term is the fact that the data is published and maintained in a decentralized manner by the different universities directly from their study program websites. After the implementation of enhanced CMS templates these tasks does not require additional effort and can be accomplished in the course of regular content editing activities. Hence data will be provided by the local actors and afterwards aggregated and visualized in a central platform (the study guide).

The prototype is concerned with three different topics with different challenges and issues. Firstly, it must be specified technically how to annotate information on university websites in a user-friendly way. The second topic encompasses the extraction of the semantically enriched information from the university websites. An architecture composed of different components will be presented. The current prototypical implementations will be explained and some aspects of data enrichment will be discussed. The third topic is concerned with the aggregation and visualization of data in a web application.

In the course of development, particularly driven by the heterogeneous requirements, an adjustment of the underlying BISE ontology became necessary. The refactored version has been published in [23]. It will not be discussed in detail in this paper.

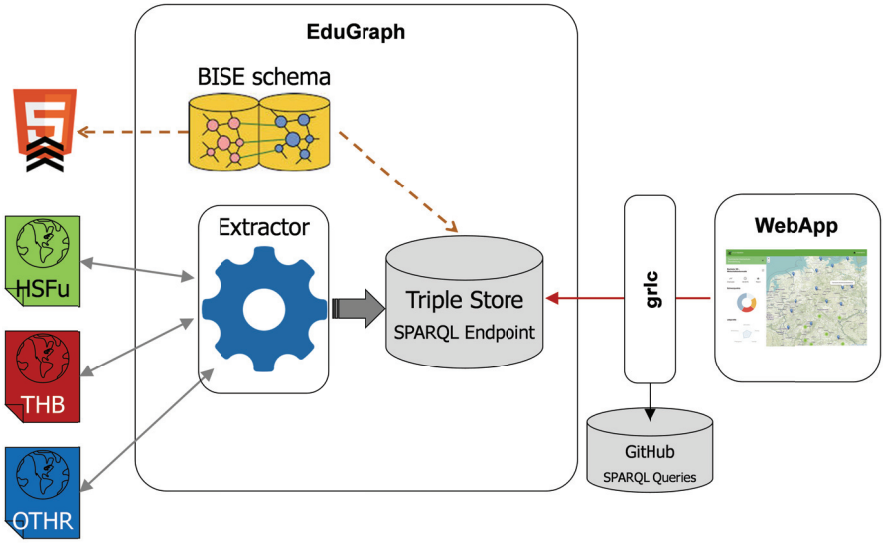
4.1. Architecture and the interaction between different components

As already explained, the basic ideas of the study guide consist of the following: (1) Universities care for semantic enrichment of their study program

websites based on the BISE ontology; (2) the annotated information get extracted from the websites and stored afterwards, and (3) a web application ensues the aggregation and visualization of that data in the form of a study guide for end users.

Figure 1 shows the to-be architecture for the decentralized study guide. Registered websites are fetched regularly, the semantically enriched information get extracted and stored in a triple store. Triggered by an information request on the user interface, the Web application addresses a Linked Data API for retrieving the requested data which then get aggregated and visualized. The API is generated based on SPARQL queries stored in GitHub and access the triple store. The architectural components concerned with Semantic Web technology are pooled under the name EduGraph.

Figure 1. Setup and overall architecture



Source: Based on [1].

4.2. Formats for annotation

There is a number of different formats usable for semantic annotation of web content, like RDFa Lite (downward compatible with RDFa), Microdata and JSON-LD. In this paper only Microdata and JSON-LD will be considered.

As mentioned in Section 3, use case 1 represents the basic necessity of semantic annotation of web content and hence shall be motivation enough for universities to realize it. It would be even more motivating, if the underlying ontol-

ogy could be used beyond a close subject domain, preferably as part or extension of Schema.org. However, this does not affect the choice of an annotation format.

The easiest way for annotation in the use cases 2 and 3 is to put semantic annotation encoded in Microdata directly in the CMS templates (see [24]). Since usually content editing tasks are performed within customized web forms containing very little free text fields, template annotation shall be effective.

The use case 4 comes out to be problematic. Two different solution approaches are conceivable:

1. A knowledgeable content editor can use the native TYPO3 rich text editor for placing annotation within the free text, which is doubtless a kind of extra effort and requires detailed knowledge of the BISE ontology.
2. Blocks of JSON-LD data can be put directly at a study program website (s. [25]). These blocks require additional maintenance. Though editors may be supported by an additional tool for the generation of semantic blocks of data (comp. e. g. [26]).

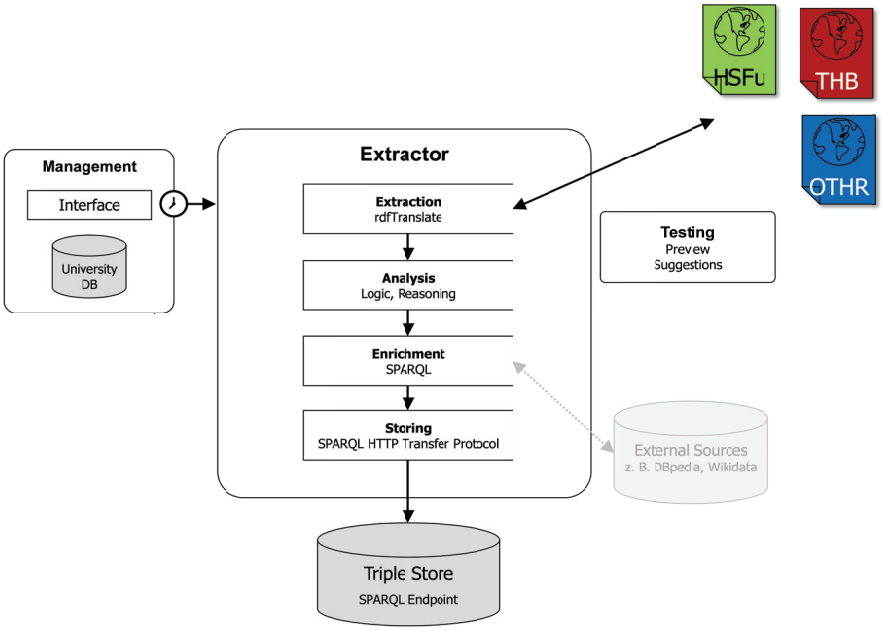
4.3. Extraction of annotated information

The extraction of annotated information is a necessary precondition for presenting them by the web application. Figure 2 presents architectural details for the implementation of a largely automated and basically quality assured extraction of information about study programs. The architecture resembles an ETL process (Extract, Transform, Load) and will be supported by other components. Following best practice in systems engineering, the extractor is not built as a completely new tool. Rather it is composed from existing technologies and can be viewed as an orchestration of several services. The extractor shall be controlled by a management module which triggers the process.

During the expert interviews it became obvious that a once-a-week cycle shall be sufficient for the extraction process. Websites of study programs are usually updated rarely and sporadically, mostly before the start of a new semester. The management module allows the administration of websites to be extracted.

The extractor itself consists of four components: The tool for the proper extraction of semantically annotated data, a proof component to check the data on plausibility and syntactical correctness, an enhancement component for adding missing information if necessary (e. g. geo information for the university based on external sources like DBpedia and Wikidata), and the triple store for the persistence of aggregated data.

Figure 2. Architectural details for the extraction of semantically annotated information



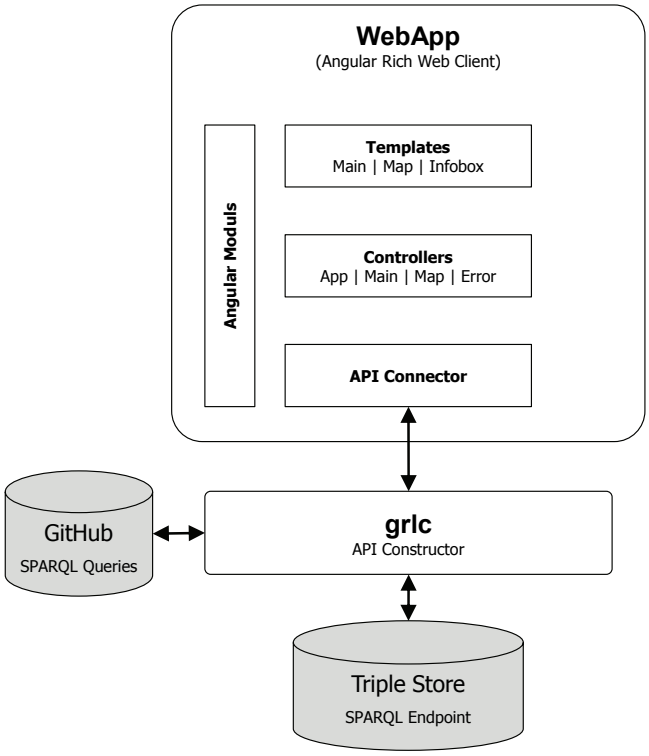
An additional testing tool is planned to reduce possible errors and allow universities a smooth start. It shall provide a preview and output of detected annotation errors and therefor support persons in charge for website content to assure the quality of annotated information. In comparison to Google's Structured Data Testing Tool it should be adjusted to the BISE ontology.

4.4. Aggregation and visualization in a web application

The study guide based on the extracted data is built as a Web application. The core of the application uses AngularJS, an open Source MVW framework (Model--View-Whatever, see [27]) developed by Google Inc. together with an active community. For the presentation, the UI framework Angular Material is used.

The structure of the Web application is shown in Figure 3. The design of each site is defined in different templates. The controller is responsible for the presentation of content, contains the business logic, and assigns data to different placeholders inside the templates.

Figure 3. Web application architecture



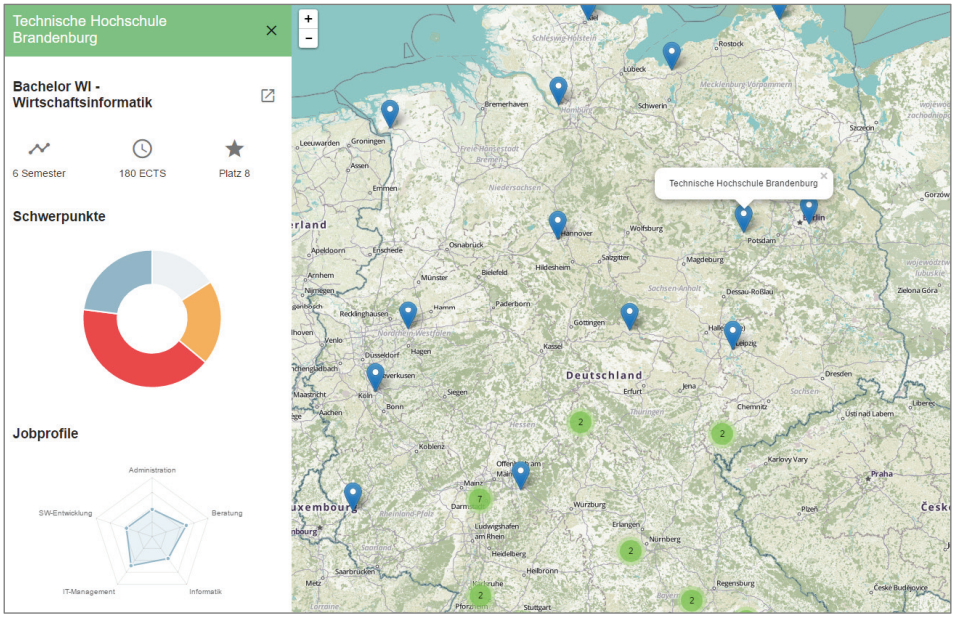
The rich Web client communicates with a triple store over a Linked Data API provided by grlc. In the first approach the Web application did communicate directly with the SPARQL endpoint via a SPARQL query service. The queries were based on SPARQL 1.1 [28] and implemented directly in JavaScript. Disadvantages were that maintaining queries inside JavaScript is difficult and Web developers are forced to have knowledge about SPARQL.

The new approach is based on grlc (git repository linked data API constructor) (see [18]), a lightweight server to provide Linked Data APIs. Grlc translates SPARQL queries stored in GitHub to Linked Data APIs and tries to use both the advantages of SPARQL and Web APIs. The API is easy to use and fit current best practices in developing Web applications. It minimizes the barrier for Web developers. The problem of using API parameters inside SPARQL are solved through the BASIL convention for the mapping Web API parameters [29]. This approach makes it easy to manage, curate and store SPARQL queries.

The Web application visualizes the focus of the different degree programs by using the four pillars of Business and Information Systems Engineering

(computer science, business administration, business information systems and complementary) (see [1]). The fitting job profiles are displayed as well. On the home page a filter is available to reduce the amount of available degree programs based on the own interests.

Figure 4. Detail page of UAS Brandenburg with a map



After filtering, the actual data is shown in a map as well as in a list of all matching universities. Selecting a university, more detailed information is displayed (see Figure 4), e.g. the duration and the available ECTS points of a degree program. Furthermore, the different pillars are visualized in a donut chart, the job profiles in a clear and easy to read way through a radar chart.

Conclusions and future work

Based on the concept acquired in [1] an operating prototype of a decentralized study guide was developed. It encompasses issues of semantic annotation and enrichment, data extraction and visualization. The technical aspects of semantic annotation are basically solved. Future work shall address the organizational aspects, e. g. by developing incentives for universities to join the system or by providing manuals for template and content editors. Without a participation of the different study programs the sketched system cannot be successful.

There must be further research how to extend the BISE ontology by covering program modules and hence to automatically derive the main subject of a given study program.

In further work, the BISE ontology should be generalized to fit other study programs. An aspiring goal could be to become an extension for Schema.org. This would be an additional motivation for universities to take part and will give a kind of confidence in sustainability and broader dissemination.

A prototype of the extractor is built, but user friendly tools for administration are missing at that point. The sketched features of testing and previewing of annotation results should be considered in future work. A particular need for research regarding the analysis of extracted information in way of plausibility and logic checks is necessary. To allow a smooth operation of service further issues of administration and operation environment shall be resolved, particularly concerning the scalability.

As a by-product the presented decentralized study guide for prospect students of Information Systems provides a structured and easy to process data base. This can be a starting point for a question answering system like described e.g. in [30] or [31]). Eventually this data base can serve as an interface to other portals and enable the automatic update of data stored there at any time the basic website is updated. Hence even the existing central study information platforms may benefit from that approach what implies further benefits for public relations and marketing at the universities which are currently responsible for the data maintenance of these central platforms.

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PROTOTYPOWA IMPLEMENTACJA ZDECENTRALIZOWANEGO SYSTEMU INFORMACYJNEGO OPARTEGO NA SIECI SEMANTYCZNEJ DLA SPECYFICZNYCH PROGRAMÓW STUDIÓW

Streszczenie: W artykule przedstawiono metodę oraz wyniki zwinnego projektu rozwoju edukacji studenta. Pierwotną była idea zdecentralizowanego poradnika dla konkretnych programów studiów, zlokalizowanych w regionie DACH (Niemcy, Austria, Szwajcaria). W porównaniu z istniejącymi systemami, analizowany w tym artykule poradnik dla studentów ma na celu zapewnienie odpowiedniej i współmiernej informacji dotyczącej programów studiów, zorientowanych na poszczególne przedmioty. Podstawową ideą jest umożliwienie semantycznego wzbogacenia każdej strony internetowej uniwersytetu o treści dotyczące programów studiów i oparte na ontologii programów studiów z dziedziny Systemów Informatycznych. W artykule poszczególne etapy rozwoju zostaną opisane z biznesowego i technicznego punktu widzenia.

Słowa kluczowe: zarządzanie edukacją, semantyczna aplikacja internetowa, ekstrakcja wiedzy, semantyczna adnotacja.