Using Semantic Documents and Social Networking in Authoring of Course Material: An Empirical Study

Saša Nešić, Mehdi Jazayeri, Monica Landoni
Faculty of Informatics, University of Lugano
Lugano, Switzerland
{sasa.nesic, mehdi.jazayeri, monica.landoni}@usi.ch

Dragan Gašević
School of Computing and Information Systems
Athabasca University, Athabasca, Canada
dgasevic@athabasca.ca

Abstract — Semantic Web technologies have been applied to many aspects of learning content authoring including annotation, dynamic assembly, and personalization of learning content as well as authors’ collaborative activities. Whether Semantic Web technologies improved the authoring process and to what extend they make authors’ life easier, however, remains an open question that we try to address in this paper. We report on the results of an empirical study based on the experiments that we conducted with the prototype of a novel document architecture called SDArch. Semantic Web technologies and social networking are two pillars of SDArch, thus potential benefits of SDArch naturally extend to them. Results of the study show that the utilization of SDArch in authoring improves user’s performances compared to the authoring with conventional tools. In addition, the users’ satisfaction collected from their subjective feedback was also highly positive.

I. INTRODUCTION

Authoring of learning content completely from scratch has always been a difficult and time-consuming task. Current research has shown that most authors reuse and modify existing content, available in their own archives or on the Web [13], rather than authoring from scratch. Therefore, if the main goal of learning content is for teaching and learning, the second goal should be its reuse. The reuse process requires a meaningful way to search and retrieve the appropriate content. Currently, only entire documents can be considered as resources that can be identified, searched and retrieved. In practice however, authors usually need only document parts, which are related to a certain concept and play certain pedagogical role (e.g., illustration, definition and example) [11]. Common selective reuse of document content is a cumbersome task, requiring copy-and-paste, which is a laborious and error prone process.

Extensive research has been carried out lately to enhance the reusability of learning content by leveraging the Semantic Web technologies for standardization and semantic annotation of learning content components [9, 11]. While these efforts have demonstrated some significant potential to improve the current state of the authoring of learning content, there are still some important issues to be addressed. Firstly, ontology-based semantic annotation is a step ahead comparing with the standardized metadata annotation, but the full potential of the semantic search will be achieved when learning content components can be efficiently searched by means of semantic annotations as well as structural and semantic relationships between them. Thus, not only the semantic annotation, but also the framework for linking learning content components and adding logical assertions over linked components is necessary. Secondly, most of the existing learning content is isolated in huge, centralized, repositories with restricted access, which is opposite of trends of the emerging Web 2.0 [1]. Thirdly, despite the fact that some authoring tools can provide some collaborative activities, most of conventional authoring tools are designed primarily for individual users and pay little attention to social activities. Finally, the use of Semantic Web technologies in learning content authoring has been reported in many studies [9, 10, 11, 12], but none of them provided any empirical data from experiments conducted to compare their authoring tools with conventional authoring tools in terms of authors’ effectiveness, efficiency and satisfaction.

Semantic Document Architecture (SDArch) is our proposal for a new, novel, document architecture that tries to address the above-mentioned issues by combining Semantic Web technologies with the strengths of the social networking. In this paper, our main focus is on the empirical evaluation of the proposed architecture based on the prototype that we have developed. The evaluation has been designed considering user effectiveness, efficiency and satisfaction in using the prototype for the authoring of course material. By quantitative and qualitative measures, we proved that our approach results in promising improvements compared to the conventional authoring approach.

II. MOTIVATIONAL AUTHORING SCENARIO

Let us suppose that Mark is a university professor who teaches ‘Software Architecture and Design’ course. For each topic in the course Mark usually prepares presentation slides that he uses during his class. The next topic to be presented in the course is ‘Design Patterns’. Mark has the presentation for this topic from last year, but he does not want to reuse it as is. In order to prepare as good presentation as possible, with up to date information, Mark plans to consider his past presentations, presentations on the same topic by his colleagues at other universities, and other related articles from his archive as well as those of his colleagues. As usual, Mark is going to use PowerPoint to prepare the presentation, as he is most confident and familiar with it. However, this time his PowerPoint is extended with a set of tools that provide him a range of new, novel services, which could roughly be put in three groups.
The first group contains the integrated social networking services that allow Mark to join the group of his colleagues who teach the same topic. Within the group, for each member Mark can access their subjective, self-estimated, expertise on the topic as well as more objective, quantitative data such as how often they are cited in the topic’s related documents, how much of their content has been reused and what is their rating in the group by the other members. Moreover, these services manage Mark’s profile and allow him to specify his preferences regarding the choice of document content for reuse. The examples of these preferences are: the ordered list of preferred network members, the ordered list of preferred document formats, and the information if the user prefers content that is reused many times, recently modified or content with many versions.

The second group contains services that enable Mark to transform his office (i.e., Word and PowerPoint) documents into a novel document data model that is completely open and queryable and that encapsulates document content into reusable, uniquely identified and semantically annotated document units. After the transformation, Mark can choose either to store transformed documents on his laptop or publish them into the group’s shared repository.

The third group contains services that enable Mark to search local and shared documents for document units by their semantics (i.e., semantic search). Moreover, these services recommend to Mark those search results, which correspond well with his preferences, by making them better ranked in the result list. Before reusing a document unit, Mark can preview its content and browse available annotations. When he decides which document unit to reuse, he can fetch it automatically, without obtaining the whole document. In addition, these services observe Mark’s behavior and track the data of his interaction with document units such as the time when he browses and reuses document units, and the way he modifies reused document units to fit to a new context.

In the rest of the paper we briefly describe our document architecture (SDArch) that provides solutions for the above listed services and the underlining document data model. Then, we present the empirical evaluation of SDArch by measuring user performances and collecting their satisfaction in using SDArch prototype for authoring course material.

III. SEMANTIC DOCUMENT ARCHITECTURE -SDARCH

The initial aim of the Web was to enable people to make their documents accessible to others by following relevant links. In recent years, we have been witnesses of a new vision that tries to provide a framework for linking data (not documents), adding logical assertions over linked data, and enabling applications that infer across linked data [1]. This vision has emerged from three distinct areas of activity connected to the Semantic Web: the Web of Data, the Web of Services, and the Web of Identity providers. Semantic Document Architecture (SDArch) is our attempt to adapt conventional office-like desktop documents (e.g., Word, PowerPoint, and PDF), so that they can contribute to this new vision. The two pillars of SDArch are Semantic Web technologies and social networking. Firstly, SDArch provides a novel document data model, namely semantic document model (SDM) [2] and a set of services for managing (e.g., annotating, searching and linking) document data of different levels of granularity. Secondly, SDArch provides integrated services [3] for organizing document authors into social networks, and modeling and including social relations and activities in the process of document authoring.

A. Semantic Document Model - SDM

SDM defines a semantic document as a composite resource built of smaller, uniquely identified, resources, namely document units (DUs) that hold pieces of document data and that are annotated by ontological and social context annotations (SCA) [3]. The ontological annotations of a DU act as the conceptualization of the DU’s semantics. SCA are used to capture the social context of DUs, that is, how users use and interact with DUs. Every time a user interacts (e.g., browses, reuses and modifies) with the DU, a new SCA data is attached to the DU. Additionally, if semantic documents hold some educational content, then their DUs can be annotated with the annotations that we introduced to specify potential pedagogical roles (e.g., abstract, introduction, conclusion, definition, explanation, description, illustration, example and exercise) of DUs. Semantic documents are implemented as RDF (Resource Description Framework) instances of SDM [2]. The RDF nodes that represent DUs have their unique URIs and can be linked with any other uniquely identified, digital or non-digital resource.

B. SDArch Design

We have designed SDArch as a service oriented architecture (SOA) with three layers. From the bottom up, they are data layer, service layer, and presentation layer.

The data layer contains the semantic document repository that stores RDF instances of semantic documents. SDArch maintains one single concept index and one single text index, which are updated every time a new semantic document is added to the repository. The concept index indexes the ontological concepts that annotate the semantic documents stored in the repository. We introduced the concept index to enable the semantic search of DUs [4]. The text index enables full-text search as a supplement to the semantic search.

The service layer provides the SDArch services that correspond with the services described in the motivational authoring scenario. All the services are encapsulated and accessible through the interface of three web services: i) User and Group Management WS, ii) Semantic Document Authoring WS and iv) Semantic Document Search WS. The data and service layer form together the SDArch middleware, which can be delivered and installed as one software unit.

The presentation layer is the SDArch top layer that provides a user interface for SDArch services. In the prototype that we have developed, we focused on extending the existing document-authoring suites, instead of creating completely new tools. In this way we enable users to take advantage of the SDArch services, while still working within familiar environments. As an example, we extended MS Office with
a set of tools that we named 'SemanticDoc'. We chose MS Office, mostly because of its wide usage and popularity.

IV. SEMANTICDOC MS OFFICE TOOLS

The SemanticDoc tools enable MS Office users to take benefits of the SDArch services directly from MS Office (i.e., MS Word and MS PowerPoint). The tools can be accessed through a new menu tab that groups the tools into five toolboxes: Account and Profile, Social Networking, Document Transformation and Sharing, Domain Vocabularies (Ontologies), and Document Recommendation. In the rest of the section we outline the main characteristics of the recommender tool, as it is essential for the motivational authoring scenario that we want to evaluate. More information, snapshots and demos of all SemanticDoc tools can be found at our project Web page1.

The recommender enables the office users to search local or shared semantic documents for DUs (e.g., paragraphs, graphics, and tables) based on their semantics, and then ranks the retrieved DUs to better correspond with the users’ preferences [3]. The tool invokes methods of the Semantic Document Search WS that perform the semantic search and the personalized ranking of the retrieved DUs. The semantic search starts by the user specifying keyword query, which is then transformed into the corresponding semantic (i.e., concept-based) query [4]. After the semantic search and the personalized ranking, the recommender shows the resulting list of DUs. For each DU, the user can browse the information extracted from the DU’s social context annotations such as the numbers and times of reuses and browses, the list of documents in which the DU has been reused, and the list of users who have reused the DU. Once the user decides which DU to reuse, she only needs one mouse click to add the DU to the cursor’s position in the active office (i.e., Word or PowerPoint) document.

V. EVALUATION

The goal of the evaluation described in this section is to investigate whether the authoring of course material can benefit from the services provided by the semantic document architecture that we developed. We formulate the following hypothesis for our evaluation:

Using semantic documents and social networking results in a more effective, efficient, and satisfactory experience, when preparing course material compared to the conventional authoring approach.

A. Design of the evaluation

In order to evaluate this hypothesis, we chose a task-based comparative evaluation [5], complemented with the goal-question-metrics (GQM) measurement model [6]. This implies asking test persons to perform a set of tasks in order to properly engage with two systems to be compared. In our evaluation scenario, one system was a conventional desktop with MS Office suite installed. The other system featured SDArch and SemanticDoc tools in addition to the conventional desktop. The set of tasks was designed to match the motivational authoring scenario depicted in Section II – create a PowerPoint presentation for the topic ‘Design Patterns’ by reusing the existing topic’s related material. By considering authors’ experience and in order to obtain both a meaningful and feasible proof of concept we decided to keep presentation to a minimum of seven slides covering: 1) Introduction, 2) Role of Design Patterns, 3) Design Patterns Definition, 4) Design Patterns Classification, 5) Pattern Example 1, 6) Pattern Example 2, and 7) Topic’s Conclusions. This limited the amount of efforts required from the participants while at the same time producing an overall presentation of an appropriate quality level. All slides had to contain certain numbers of textual items and slides 5 and 6 should also contain graphical illustrations of the chosen example patterns. Even if this sounds pretty restrictive, the aim was to set up a controlled environment where comparing effectively experiences across the new and conventional system for producing presentations, while still encouraging test users to use their creativity and expressivity.

In our evaluation six participants, from three universities, took part. All participants were volunteers and had genuine motivation in using the new systems. Moreover, each participant had been involved in some courses covering the topic of our evaluation scenario, either as a lecturer or teaching assistant. Thus, they qualified as domain experts and final users of the services too. The evaluation procedure started with the preparation phase. Two weeks in advance of the evaluation session, we initiated ‘the design patterns interest group’ using our social networking services available through SemanticDoc tools and added 20 documents from our archive to the group’s semantic document repository. These documents represent a complete document set that we had considered while preparing the presentation that we used in our course given at the University of Lugano. Then, we asked the participants to join the group, to transform no less than 5 documents (i.e., Word and PowerPoint) from their archives, and publish such transformed documents in the group’s semantic document repository. In this way, we expected to have all together around 50 documents available during the evaluation session. According to the authors’ experience, 50 is a reasonable number of documents to use in this scenario. It was also expected that the feedback from this preliminary evaluation would enable us to set the right threshold for this value for the further evaluation in the future. For the semantic document annotation during the transformation process, all participants were required to select the same domain ontology, which we added to the group’s ontology repository. Since we planned to confront the conventional system to our system, we also asked each participant to send us the original documents, so that we could make them available to the other test persons. The total number of documents we received was 41 (i.e., 6.83 documents in average per test person), which was slightly more than we had expected. We skim read all the documents and for each document created a table of contents (TOC), so that during the evaluation session the participants could easily guess the contents of the documents. Moreover, we put all collected documents into a temporary Web repository to be available for download during

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1 SDArch Web page: www.semanticdoc.org
the evaluation session. In addition, we need to point out that our goals with the preparation phase were to create a social network and to collect the evaluation document set, as much as to familiarize the participants with our system.

Following the GQM model, we considered user effectiveness, efficiency and satisfaction as main evaluation criteria and defined qualitative and quantitative measures for them. For user effectiveness, we planned to measure how effective participants were in completing the evaluation tasks. Thus, we tracked how many and which tasks participants could complete successfully by using the two systems. Considering user efficiency, we planned to measure how efficiently participants were in completing the evaluation task. Thus, we measured the execution time, the number of mouse clicks and the number of window switches. Finally, for user satisfaction, we wanted to evaluate which test system the participants liked more and why. To gather feedback from the participants on satisfaction, we used a questionnaire that we created by selecting questions from the Perceived Usefulness and Ease of Use questionnaire [7]. We expected participants to implicitly and naturally refer to their previous experiences in using the conventional system when considering the performance of our system. Nonetheless, we set up a more formal comparative experiment making all participants engaged with the same documents and tasks via the two systems. This way we could extract a richer set of data to be compared in order to address our hypothesis and related research questions in terms of evaluation criteria.

B. Conducting the evaluation

The evaluation session consisted of two phases, namely observation and feedback. In the observation phase, we were observing the participants and tracking their behavior using screen recordings while they were conducting the evaluation tasks. To avoid asking the participants to install the software for the screen recording and to simplify the manipulation of the recorded material, we asked the participants to take the evaluation tasks on our PC with remote access control. All they needed to use was remote desktop control software for remote PC access and control. Four out of six participants already had the software installed on their laptops and were familiar with it. For each participant we created an account on our PC and provided them with credentials for the remote access. The participants were split into two groups of three persons. The first group was asked to execute the tasks first by using the conventional system (i.e., MS Office without using SemanticDoc tools) and then using our system (i.e., MS Office with SemanticDoc tools). The second group used the test systems in the opposite order. Each participant was allowed to do the evaluation tasks within two given days at the time they prefer, but in two separate, continuous time sessions, one for the conventional system and the other for our system. The sessions started and ended by the participants activating and deactivating the recording software.

The observation phase was followed by the feedback phase, where we asked the test persons to fill-in our online questionnaire. The questionnaire was composed of the following 9 statements:

S1: Using SemanticDoc enables me to accomplish tasks more quickly;
S2: Using SemanticDoc increases my productivity;
S3: Using SemanticDoc improves the quality of the work I do;
S4: Using SemanticDoc makes it easier to do my work;
S5: Overall, I find SemanticDoc useful in my work;
S6: Learning to operate SemanticDoc is easy for me;
S7: I find it easy to get SemanticDoc to do what I want it to do;
S8: Interaction with SemanticDoc is clear and understandable;
S9: Overall, I find SemanticDoc easy to use;

The participants were asked to rate each of the statements using theIsoMetric five-point rating scale [8], starting from 1 (predominantly disagree) to 5 (predominantly agree). The first 5 statements from S1 to S5 were to gather subjective evaluation of the system usefulness. The following four statements from S6 to S9 were to gather subjective evaluation of the ease-of-use of the system.

C. Evaluation results

By analyzing data recorded during the observation phase, we gather indications about user effectiveness and user efficiency.

With respect to user effectiveness, we tracked how many and which tasks participants completed successfully. All test persons completed successfully all tasks, using both systems. In our opinion this result is mostly due to time-unlimited sessions and the ability of the participants to set the evaluation sessions at preferable time as well as their genuine motivation to participate to the evaluation.

![Figure 1. Average and Median Execution Times for Task 1-7](image)

With respect to user efficiency we measured the execution times, the amount of mouse clicks and the number of window switches during the tasks executions. Figure 1 presents the measurements for the task execution times, including values of average and median execution time, for each task for both systems. Table II and Table III show the average and median numbers of mouse clicks and window switches for each task, respectively. Additionally, the relative performance of the participants when using our system with respect to participants when using the conventional system is shown as percentage. For example, a value of 70% indicates that participants using our system needed 70% of the mouse clicks (or window switches) that participants using the conventional system needed.
approaches still pay little attention to social aspects in the authoring of learning content, which focuses on the relations between authors and the way authors use and interpret the learning content. Moreover, there are approaches [11, 12] that use Semantic Web technologies to support dynamic assembly and personalization of learning content.

Although the use of Semantic Web technologies in the authoring of learning content has been studied extensively, the real benefits of their applications are still unclear due to a lack of empirical evaluations. In this paper, we presented the empirical evaluation we conducted to investigate the benefits of the proposed, novel, semantic document architecture (SDArch), with respect to the authoring of the course material. Based on measured results of user effectiveness and efficiency, and the users’ subjective feedback, we found that the utilization of SDArch results in improvements for the authoring of the course material compared to the utilization of conventional authoring tools. Since the Semantic Web technologies and social networking are two pillars of SDArch, the benefits of SDArch naturally extend to them. In the future work, we will provide further (statistical) analysis of the collected data (e.g., statistical significance of the obtained results between the two groups – our system vs. conventional; and types of DUs reused by the two groups).

### References


### Table I. Average and Median Number of Mouse Clicks

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### Table II. Average and Median Number of Window Switches

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### Table III. Subjective Feedback for Our System

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### VI. Related Work and Conclusions

Extensive research has been carried out lately on the application of Semantic Web technologies to different aspects of the authoring of educational material. There are numerous approaches such as [9] that attempt to standardize and semantically annotate learning content components, and to make them usable in interoperable content repositories. However, most of the existing learning content repositories are huge, centralized repositories, which is contrary to the trends of emerging Web of interconnected data [1]. There is also a lack of integration of most frequently used authoring tools with the existing repositories. Other approaches such as [10] try to integrate ontologies and the Semantic Web protocols into collaborative authoring of learning content, but these