eRoDes: a Web-based Framework for the Development of Semantic-Enhanced Learning Objects

Pedro Álvarez, Sandra Baldassarri

Department of Computer Science and Systems Engineering
University of Zaragoza, Spain
Email: {alvaper,sandra}@unizar.es

***Abstract*—Learning objects are often created reusing multimedia resources available in the Web. The metadata of these new objects are usually annotated using semantic technologies. Nevertheless, some relevant challenges related to the creation of semantic-based metadata and their use in learning experiences are still open. The combination of solutions of service-oriented computing, Linked Data Cloud and semantic technologies allows to tackle these challenges. The result is *eRoDes*, a web-based and service-oriented framework able to semantically annotate learning objects in an automatic way and that provides services for the development of learning activities using these objects. *eRoDes* functionality has been tested in a subject of Computer Engineering's Degree at the University of Zaragoza during 2014-15. The results are reported and discussed.**

***Keywords*–Semantic annotation; learning objects; web services; e-learning.**

I. Introduction

The Internet provides a huge amount of multimedia resources, such as videos, audio, web pages, documents, etc. These resources can be useful in the design and creation of new learning objects. However, in order to include these objects in teaching experiences it is necessary to previously describe their metadata, which consist of annotations that help users to classify, recover and share the learning objects. Semantic technologies have been integrated into e-learning systems to enrich these annotations and allow to improve the management of the learning objects stored into the repositories. Nevertheless, in the field of e-learning, some open challenges must be still addressed in relation with: the automation of semantic-annotation processes, the validation of annotations from the user's perspective, the linking of new learning objects with other Web-accessible resources, and the interoperability of solutions to access and exchange these objects.

In most of the studied semantic-based systems [1]–[7], the annotations are manually created by users' or by domain experts'. Nevertheless, they differ in the origin of the annotations. In several systems, annotations are based on the contents of the learning objects and are created using domain ontologies [3]–[7]. These systems are only able to work with video while other works deal only with textual resources [1][2]. Annotations, in these cases, could be indicators about the complexity for the learners to understand the concepts related with the learning objects [2] or pedagogical terms extracted from the text-based comments and manually added by the teachers to the learning objects [1]. On the other hand, there are some automatic annotation tools, but they are not focused in the contents. The annotations can be generated by assigning categories extracted from synthatic structures of the text [8] or, instead, they are generated after processing the multimedia resources in order to automatically extract visual features that provide knowledge about the contents [9][10].

Once the learning objects have been semantically annotated, it is necessary to validate the usefulness of these annotations for learners. Most of the manual annotation tools previously mentioned have not implemented feedback mechanisms to improve the annotations since they are supposedly created by experts. The system presented in [4] is an exception. There, the system monitors the interactions of the learners with the objects and with other participants and uses this feedback information to identify resources that could be improved. On the other hand, there are other approaches that propose the use of collaborative techniques to improve their annotations [11][12]. Learners review peers' annotations and provide ratings or comments that will be used to re-annotate the learning objects.

Finally, the annotation systems should use standard ontologies to describe the metadata of new learning objects. The use of standards makes the linking of new objects to other online resources easier. Although the existing systems are prone to work with proprietary ontologies, some works propose as an alternative the use of vocabulaires of the Linked Data Cloud [13] to link their annotations to external data sets [3][6][7]. On the other hand, the standarization also helps e-learning systems to access and exchange learning objects between them [14]. Unfortunately, most of the existing e-learning systems are monolithic solutions that integrate a non-web editor to create semantic annotations and a web browser or application to search and recovery the annotated objects.

eRoDes, acronym in Spanish of "crEación participativa de RecursOs Docentes Etiquetados Semánticamente" (collaborative creation of semantically annotated learning objects, in English), is a web-based and service-oriented framework that allows to semantically annotate learning objects and stores these objects and their Resource Description Framework (RDF) based annotations. Unlike other existing approaches, the annotation process is automatic, without users' or domain experts' interaction, it uses vocabularies of the Linked Data Cloud (the learning objects are linked to the DBpedia) and annotations are created from the content of different kind of resources (the text of a web page, or the audio of a video, for instance). This process has been implemented by integrating external web services, Linked Data algorithms and semantic technologies. Two different voting mechanisms are provided in order to validate and to improve the annotations that were automatically created. Moreover, *eRoDes* integrates a set of software components to design learning and teaching activities.

These components are basic functional units that work over the annotated learning objects and that have been implemented as services to facilitate their reusability and integration into e-learning applications or workflows.

In order to show the use of this framework, a learning activity is described. The activity is aimed to involve students in the creation of new learning objects: searching, classifying and assessing resources available in the Web. The created objects have been submitted to *eRoDes* to be semantically annotated and afterwards used in the teaching of a subject. Also, the students provided feedback in order to improve the annotations of new learning objects created by other students.

The remainder of this paper is organized as follows. Section II presents the architecture of *eRoDes* framework, while in Section III implementation's details are described. In Section IV, a complete learning-teaching activity is explained, including its phases and the results obtained. Finally, the most important conclusions are presented at Section V.

II. THE ERODES FRAMEWORK

Figure 1 depicts the high-level architecture of the *eRoDes* framework. It is a service-oriented system that has been implemented using web-based and semantic technologies. The framework provides two types of services: 1) Submission services that semantically annotate new learning objects and store them into the knowlegde database of *eRoDes*, and 2) Application services that automate some tasks of learning activities planned by teachers.

Students and teachers can submit new learning objects, such as text documents, PDF files, or videos, to the framework using the Moodle application or the *eRoDes* web-application. The submission services are implemented as a semantic annotation process that automatically annotate these objects before storing them into the knowledge database of the system. These annotations are generated from the content of each object and mapped on an ontology which was previously defined by the teachers or automatically created by the system from the teaching guide of the subject.

As it can be observed in the left part of Figure 1, this semantic annotation process consists of a linear pipeline of three stages: Resource preprocessing stage, Extraction of relevant terms stage and Annotation process stage. This pipe has been designed following the Pipes and Filters architectural pattern [15] in order to make easier the exchange and the recombination of filters, the rapid prototyping of pipes and the parallel processing of the different stages. The pipe was implemented by the integration of web-accessible services and libraries developed in the field of Semantic Web.

From the execution point of view, some stages could be computing intensive processes (more precisely, the speech-to-text translation of a video when its duration is long) or an user could request the annotation of a large collection of learning objects. Thus, the pipe components have been programmed to be optionally deployed in some of the distributed computing infrastructures at our disposal. For this purpose, the HERMES computing cluster hosted by the Aragon Institute of Engineering Research and the clouds provided by OpenShift and Amazon have been integrated in the *eRoDes* framework. This remote deployment is configured, executed and monitored by the mediation layer developed in [16]. This layer provides a transparent and easy-to-use access to the set of hybrid computing infrastructures. So that, these heterogeneous infrastructures are viewed as a whole by end-users.

On the other hand, the right part of Figure 1 shows the application services offered by the current version of *eRoDes*. An application service provides a coarse-grained functionality that will be used in learning activities by students or teachers. These services access and use the annotated objects that had been stored into the knowledge database of *eRoDes*. Until now, three student-oriented services and two prototypes of teacher-oriented services have been implemented in order to provide the following functionality:

- the validation of annotations service allows a student to improve the semantic annotations of a learning object,
- the ranking system helps students to assess the quality and usefulness of the objects submitted by other students,
- the understanding system allows to create a mind map that represents the understanding of a student after working with a learning object,
- the quality resource evaluation service is used by teachers to evaluate the quality of resources created by students,
- and, finally, the learning process evaluation service provides teachers with feedback about if students learn what they should when working with a specific object.

All these services expose their functionality as web services in order to make easier their integration in different applications. As it will be described in next section, the services for improving and ranking learning objects have been integrated into PyBossa [17], an open-source framework for crowdsourcing. With this tool, students will improve the semantic annotations of objects created during an activity or a course.

III. IMPLEMENTATION OF ERODES

In this section, the *eRoDes* main components involved in the semantic annotation of learning objects and the validation of these annotations are described in detail.

A. Semantic annotation process

The skeleton of the semantic annotation pipeline has been implemented in Java and is based on the Pipes and Filters pattern: each processing stage has been implemented as an individual component and the connections between stages as buffers that synchronize the data flow between adjacent components. These components and buffers are called filters and pipes, respectively. First, a version of this architectural pattern based on Java interfaces was programmed. Afterwards, all the filters and pipes that compose the pipeline have implemented these interfaces. The web-accessible services and the semantic libraries and technologies used in these implementations are described in detailed in the next paragraphs. This interface-based implementation makes easier the integration of components in the pipeline and their future update and maintenance.

The first stage of the pipeline is executed by the resource preprocessing component. A different preprocessing component has been programmed for each kind of input object.

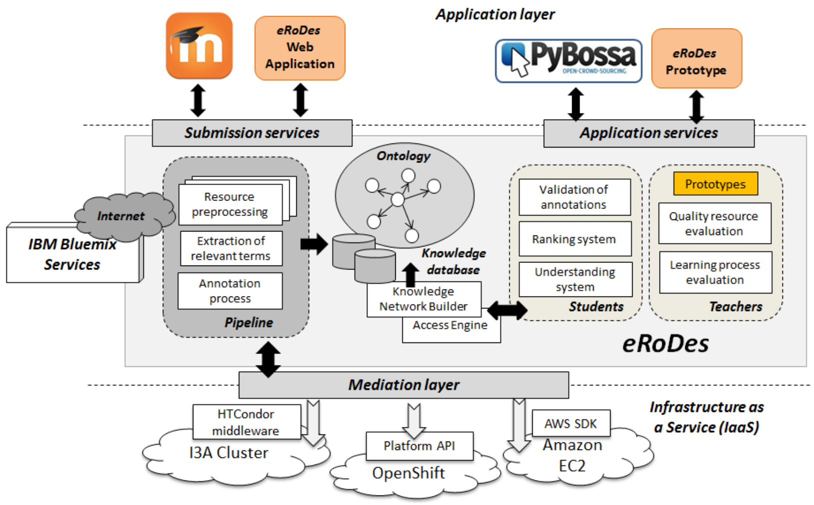

Figure 1. High-level architecture of the eRoDes framework

On the one hand, videos are preprocessed using the Java Audio Video Encoder (JAVE) library and a speech-to-text service provided by the IBM Bluemix platform [18]. Different alternative technologies have been studied in this stage. For video preprocessing, JAVE was compared with Xuggler [19], but, alghough both have similar features, JAVE proved to be simpler. Regarding speech recognition, several web services and libraries have been considered. One of the most known web services, Google Speech API was analysed. But the input audio is restricted to 15 seconds and the daily requests to 50 in the free version, while IBM Bluemix platform allows 3 minutes for the input audio time and there is not limit for requests. The CMU Sphinx library [20] was also considered in order of not depending on the web or on external services. However, quality and performance tests shown that IBM Bluemix platform is twice faster and offers 30% better accuracy in word recognition. In our implementation, JAVE extracts the audio of an input video and is capable of converting it to different formats. Then, the resulting audio file is sent to the IBM Web service to be transcribed into a text file. On the other hand, documents are preprocessed using Apache PDFBox library. The text of PDF documents is extracted and transcribed to an output text file.

Following, the extraction of the relevant terms stage has been implemented by integrating the Java Automatic Term Extraction toolkit (JATE). This toolkit provides a set of Automatic Term Recognition (ATR) algorithms that will be used to determine the most relevant terms of the text-based transcriptions [21]. We have selected the ATR algorithms capable of recognising both single-word and multi-word terms and that do not discard candidate terms only on the basis of frequency. The execution of each algorithm generates an output file that contains the recognised terms; then, these files are processed by an automatic voting component to select the most relevant terms. In our solution, two different strategies based on a weighted and majority voting have been combined: first, a weight is assigned for each recognised term based on its rankings and, then, the terms that received the greatest total weighted vote are selected.

Finally, the annotation process is responsible for annotating semantically the most relevant terms. This last stage integrates an implementation of the ADEGA algorithm [22]. ADEGA annotates each term by means of a RDF graph created from those instances of the DBpedia that are relevant in the resource domain. In our solution, the resource domain is defined from materials provided by the teachers, the guide or the slides of a subject, in order to link the annotations of learning objects with the context where they will be used. An RDF graph is created for each specific term and stored into a Virtuoso database [23]. Then, these graphs are used to classify the input learning resources, facilitating the search and retrieval of information.

B. Application services

The service for validating the semantic annotations of the learning objects is one of the most used application components. The validation of annotations consists of accepting or discarding each term that was automatically generated by the annotation pipeline. A web application, based on the front-end of PyBossa that allows students and teachers participate in the validation tasks, was programmed. A PyBossa microtasking project publishes the list of objects waiting to be validated. Registered users can access to these objects and check if the terms associated to a specific object correspond with its content. A term can be accepted/discarded or new terms can be optionally added. These decisions are then sent to the *eRoDes* validation service in order to improve the object's annotations and update the knowledge database of the platform.

Figure 2 shows the components involved into the validation system. A bridge component interconnects the web service with the PyBossa core. It translates the list of unvalidated objects returned by the service to a set of PyBossa tasks. These tasks are JSON objects with the information that needs to be completed by the user during the validation of annotations process.

A new task creator has been programmed to upload these tasks into the PyBossa core via its RESTful API. Then, these

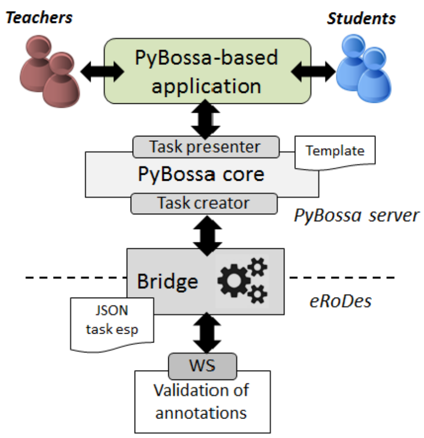

Figure 2. Validation based on the PyBossa framework

tasks are presented to students and teachers through a web-accessible interface which was previously created in a PyBossa server. We have reused an existing template for programming the task presenter, the module in charge of presenting the pending tasks and submitting the user decisions to the *eRoDes* framework. This presenter has been implemented in HTML and JavaScript. Finally, from the deployment point of view, the PyBossa server and the *eRoDes* framework are installed and run in the same server. Nevertheless, the API-based integration of services makes easier the possibility of configuring a distributed deployment.

IV. A LEARNING-TEACHING ACTIVITY BASED ON THE USE OF ERODES

In this section, an activity developed during 2014-15 in the subject Design of User-Centered Interfaces, of Computer Engineering's Degree is presented. The activity's objective is to involve students in the creation of learning objects. During the development of this work, students have to search, classify and assess teaching resources available in the Web and the resulting learning objects are stored in the *eRoDes* framework and used for teaching the subject.

A. *Phases of the activity*

The phases planned for the learning-teaching activity are shown in Figure 3. In the Initial phase, the teacher proposes some specific topics for the learning objects. These topics, together with the pdf document of the teaching guide of the subject, are sent to the *eRoDes* framework.

The objective of the First phase is the creation of the learning objects. At the beginning, the students are organized in groups of three (this number may be modified depending the class size) and a different topic is assigned to each group. This first phase consists of two sequential tasks: the resource searching and the developing of guide notes. In the first task each student individually searches resources and materials that could be useful to create the learning object. The teacher must previously define the maximum number of selected resources. Subsequently, the second task, performed in groups, involves the assessment of the resources contributed by each member of the group, in order to decide those materials that will be more suitable for the creation of the learning object, and, finally, to create it. In our proposal, a learning object consists of a limited set of resources and guide notes that determine how to use them for achieving the teaching objective. The guide notes allow to know, for example, the order in which the resources must be used, the knowledge that should be acquired with each one, or the relationship between the content of the different resources, among others. Finally, each group must submit the guide notes and the selected and discarded resources to *eRoDes* to be semantically annotated and stored into the knowledge database. Besides, a short explanation to justify the final decision of discarding an specific resource is required.

The Second phase of the activity consists of two individual tasks: the evaluation of guide notes and the activity assessment. In the first task, students must download the semantically annotated learning objects created with *eRoDes*. Then, each student must use these objects following the instructions provided by the guide notes developed by the other groups and has to evaluate their usefulness for learning the corresponding topic. This evaluation is based on peer review techniques. A PyBossa project has been created to interact with *eRoDes* and provides students a template to evaluate each learning object. The template also allows students to add or delete the semantic annotations of the downloaded resources, in order to improve these annotations in the *eRoDes* system. Once the evaluation is completed, in the assessment task students evaluate the activity by means of a questionnaire which gathers their opinion about their involvement in the activity, the experience of working in group, the strengths and weaknesses of the learning object created by their group, and about possible improvements in the planning and development of this kind of activities.

During the two first phases students must control the time dedicated to the planned tasks. A time tracking report is delivered to teacher at the end of the activity in order to know the effort dedicated by students. However, this information does not have influence over their final grades. In parallel, the teacher also evaluates the set of learning objects creating a reference evaluation, that will be used in the following phase.

Finally, the Third phase corresponds with the grading of the activity, in which the teacher determines the final marks for the work done by the students. This grading is based on the teacher's reference evaluation and the students' peer review. Besides, the teacher analyses the learning process and the questionnaire results in order to write a final report with the main conclusions and an activity improvement plan.

B. *Results*

There were 16 students in the subject during 2014-15, which have been organized in four groups of three persons and two groups of two persons. The six topics selected by the teachers were: Agile software methodologies and User eXperience design (UX Agile), Usability evaluation, Accessibility evaluation, Crowdsourcing methods, Adaptative design and Wearable interfaces. Each student of a group must search resources of a specific format, in order to have at least two or three different kind of resources.

Figure 4 shows an overview of the results of this experience. The first row represents the number of resources found by each group after completing the searching task. The teacher defined that the maximum number of resources per student was 6. In general, these resources were found using Google and Google Scholar, DuckDuckGo, and YouTube, being videos

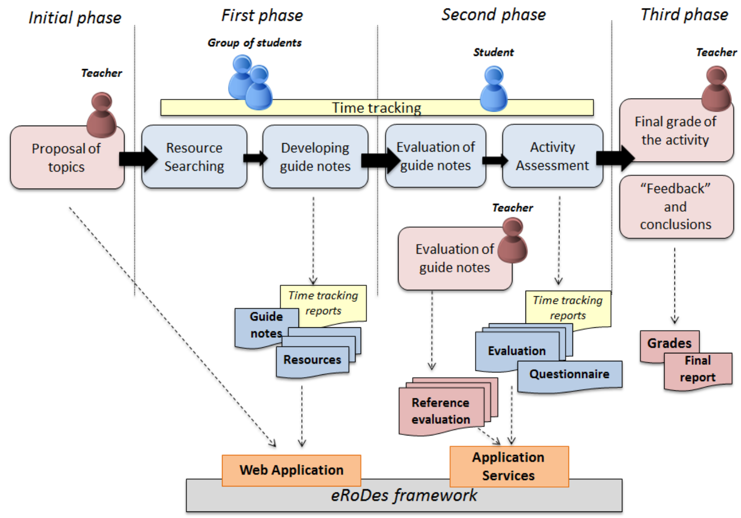

Figure 3. Phases of the learning activity

	UX Agile	Usability	Accessibility	Crowdsourcing	Adaptative design	Wearables	
Num. of found resources	15	25	23	18	18	11	Phase 1
Number of videos	7	6	4	6	2	5	
Number of documents	1	6	8	4	3	6	
Number of Web pages	5	8	4	8	11	0	
Number of tools	2	5	7	0	2	0	
Improved annotations	1	4	16	1	12	4	Phase 2
The students' gradings	8,6	7,1	7,9	7,3	6,2	8,5	
The teachers' gradings	8	6	9	7,5	5	9	
Hours per student (Phase 1)	5,3	2,75	4,25	1,4	5,8	4,25	Time tracking
Hours per student (Phase 2)	4,4	3,9	1,4	4,2	4,5	1,5	
Hours per group (Activity)	29,2	20	11,3	16,8	30,8	11,5	

Figure 4. Indicators related to the development of the activity

a 30% of resources. 55% of these resources were in English and 45% in Spanish. It must be taken into account that the topic had influenced over the format of found resources. For example, most of the Usability or Accessibility resources were tools. Finally, all the groups must select 7 resources to develop their guide notes. Once the First phase was completed, all the guide notes and resources were submitted to *eRoDes* to be semantically annotated by the framework. Figure 5 shows one of the graphs that were created to semantically annotate a video about Crowdsourcing methods. This video is available at https://www.youtube.com/watch?v=-38uPkyH9vI. The graph corresponds with the term Expertise which is a relevant concept extracted from the contents of that video. Its depth was limited to three levels of exploration and all types of relations were not explored. From the computational point of view, video annotation was the most compute-intensive operation. For example, if the speech-to-text service provided by the IBM Bluemix platform is invoked, the time needed to extract the text of an audio is proportional to the input video duration.

On the other hand, also the students's grading and the teachers's grading of each group can be observed at Figure 4 in rows 6 and 7. In general, both gradings are very similar and have been calculated from the rubric results. The aim of this rubric is to evaluate, mainly, the suitability of the selected resources, the usefulness of the guide notes, and the learning level that a student could achieve using them. Besides, 7 students proposed to modify some of the resource annotations via the PyBossa application: more specifically, the semantic annotations of 16 resources were modified, 103 resources had been submitted to *eRoDes*, and most of these changes belong to usability and accessibility resources.

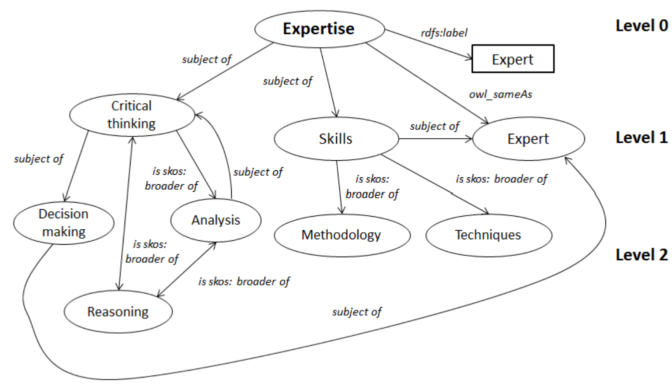

Figure 5. Graph example for the Expertise term

Finally, an overview of the time dedicated by the students is also presented. Rows 8 and 9 show the amount of hours individually dedicated to complete the first and second phase, respectively, while the hours dedicated in group to complete the whole activity is in row 10. In some cases the times reported by the students are below the time expected by the teachers. For example the time dedicated by the crowdsourcing, the accessibility and the wearable interfaces groups were insufficient. It is possible that some of these time trackings were wrong, since the students are not used to monitor their work hours. Therefore, in future activities, our rubric evaluation must be improved in order to detect these situations.

From the analysis of the results obtained from the questionnaires, the students evaluation and also during the development of the activity, some changes should be introduced in next courses. Following, the main proposals included in the activity improvement plan are summarized. Firstly, students must be trained in the gathering and assessment of resources and in the creation of guide notes. Teachers must define more precise instructions on how to make these tasks and provide students with meaningful feedback during the activity. An active role of teachers will help to improve the quality of guide notes and learning objects and, therefore, their reusability in this subject or in other similar subjects. Secondly, all the topics proposed to students should be equally motivating for them. And, finally, the evaluation of learning objects and their usefulness in the learning process must be students and teachers responsability. Besides, for the future course teachers have decided to replace the guide notes by a short-length video which will be created from learning resources found by the students.

V. Conclusions and future work

A new service-oriented framework to store and retrieval semantic-enhanced learning objects has been presented in this work. Its interface provides functionality to semantically annotate learning objects from a wide variety of formats. These annotations are automatically created from the contents of input learning objects and are expressed as RDF based graphs built from the DBpedia vocabulary. We selected the ADEGA algorithm because it obtained better results for precision and recall values than other semantic and DBpedia based annotation algorithms [22]. The system also provides functionality to validate the usefulness of these ADEGA-based annotations from the users' perspective. Nevertheless, the objective is not only to support the annotation and validation of learning objects, but also to facilitate their use in the development of learning activities. Application services facilitate the integration of the functionality of *eRoDes* into different e-learning applications.

As future work we are interested in improving the interoperability of *eRoDes* by the integration of standards for the description, discovery and retrieval of learning objects. We will also study the usability of our application to create new online learning contents by means of a System Usability Scale (SUS). On the other hand, another open challenge is to evaluate the quality of new learning contents and validate their usefulness in the learning and teaching process. On this regard, a first solution based on semantic technologies and graph algorithms is being tested in the same subject during this course. Also, a new *eRoDes*-based application able to provide feedback about the students' learning process is now under development.

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