BOAv3 – Learning Object Pool

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ABSTRACT

Learning Object Repositories (LOR) support eLearning experiences by providing mechanisms for its coupled community of users to publish, search and retrieve educational resources. Moreover, when these resources of varying granularities are formally described by means of metadata they are denominated Learning Objects (LOs) which, in turn, enables them to be reused or aggregated with other LOs in the educational scenarios attuned to the preferences of the LOR user.

Bolsa de Objectos de Aprendizagem (BOA, or, in English, Learning Object Pool) is an ever evolving LOR whose efforts aim to aid the educational tasks of its user base.

This paper reports the research findings on the current state of the art in the Technology Enhanced Learning (TEL) knowledge area, details a multi-faceted solution supporting the evolution of BOA by means of a LOR evaluation framework and validates it with a qualitative evaluation against other notable repositories.

The proposed solution comprises the exposure of BOA's LO metadata records to external applications, the adoption of social interface patterns, the automatic scoring of several repository asset's reputation, the incorporation of personalization features in search mechanisms, among other aspects.

The advantages and impact of evaluating repositories in a controlled manner through a framework thus driving the decisions of both developers and educational software designers are analyzed and discussed.

It is concluded that the application of the LOR evaluation framework proposed in this paper contributed towards a qualitative improvement of BOA whose features in its latest version not only leverage the discoverability of its LOs but also the growth, commitment and engagement of its user base.

Keywords

Learning Objects, Learning Objects Repository, Learning Object Metadata, Technology Enhanced Learning

1. INTRODUCTION

The establishment of the Internet as the primary mechanism for communication and knowledge sharing in a global scale brought forth new needs and opportunities for education while being simultaneously leveraged by technology. The knowledge area that emerged from this is called Technology Enhanced Learning (TEL) [14, 15, 27, 30, 33, 34].

The concept of Learning Objects (LOs) in TEL are digital files that when properly described in a controlled and standard manner with metadata, provide valuable ways for both instructors and learners to find, share and reuse these resources in an educational context [1, 2, 3, 40]. However, in order for these actors to make use of LOs, a LO Repository (LOR) is required for proper maintenance of metadata and providence of the above mentioned functions.

Over the years several efforts have been made towards designing and implementing LORs, and while some were successful most of them struggle with recurrent problems concerning building a community surrounding Learning Objects. The most time-resilient LORs successfully endured through time based on their capacity of increasing the number of available LOs progressively enriching their repository with potentially valuable, high quality submissions. Those submissions depend however on the capacity of a LOR to deploy a set of features that effectively promote the engagement, good will and altruism of its community members since producing high quality educational resources is a costly and time-consuming task [8].

BOA (in Portuguese, *Bolsa de Objectos de Aprendizagem*) is an ongoing project of a Learning Object Repository web application. Developed by the research laboratory INESC-ID and with two functional instances currently deployed, respectively VemAprender and BOA-GPI, the BOA project aims to support learners and instructors with the providence of properly catalogued learning objects to be reused in their educational activities [41, 42, 51, 52, 63].

On the same note, BOAv2 suffers from a lackluster user community and LO centric engagement as reported by Silva in [42]. In this manner the following primary problems emerge in BOA's current version:

- How to achieve an abundance of LOs?
- How to achieve an abundance of users?
- How will users be brought in, kept active and behave collaboratively?
- How can users search LOs in a personalized fashion?
- How will the LOs be made discoverable for outside sources?
- How will the users and LOs be managed?
- How to identify and reward valuable repository assets?

The answers to these questions were obtained with the application of a LOR evaluation framework to BOAv2 which, being based on the research effort behind this body of work, was revealing of BOAv2's shortcomings while simultaneously projecting possible solutions for BOAv3. The overall solution, although multi-faceted and specific to BOAv3, can be extrapolated for other repositories as the above mentioned problems are recurrent in this particular type of eLearning applications.

In order to validate the solution and ascertain how comparable BOAv3 is against successful repositories like ARIADNE, MACE, MERLOT and Connexions, a LOR evaluation framework was applied to these LORs. It was proven that BOAv3 positively distinguishes itself by deploying a set of features which have the potential to be notoriously impactful in their own right such as the exposure of a SPARQL endpoint for LO discoverability purposes, an automatic metadata quality control mechanism, the offering of a variety of personalized search facilities to aid the retrieval of educational resources, the adoption of social interface patterns or the deployment of a reputation system to measure important repository asset's popularity, among others.

This paper is organized in the following sections: Section 2 reports the related work that was found applicable to Learning Object Repositories and BOA in particular. Section 3 describes the solution and implementation details regarding BOAv3 while being organized in sub-sections according to the dimensions of the surfaced LOR evaluation framework. Section 4 details a qualitative evaluation of BOAv3 against not only BOAv2 but also other notable LORs. Section 5 concludes this paper by specifying the insights that were obtained during the evolution process of BOAv2 towards BOAv3 and the main contributions that can extrapolated for the research community from this body of work.

2. BACKGROUND

This section presents the related work organized into four pertinent sub-sections each of them containing knowledge which contributed decisively to the emergence of the LOR evaluation framework that was applied to BOAv2 and BOAv3 in section 3.

2.1 General concepts about Learning Objects

According to Richards, et al [1], in a nutshell, Learning Objects (LOs) are digital objects or files that when adequately catalogued and used constitute "building blocks" for the construction of eLearning experiences. The cataloguing of those digital files, when made through the use of metadata, enables the creation of the above mentioned Learning Objects. Metadata describes LOs in a controlled manner according to the needs of the users of a certain learning community.

In turn, the same learning community which is tightly coupled with a Learning Object Repository is provided with the basic features for the management of Learning Objects, such as proper warehousing, indexing, cataloguing, searching, sharing, etc.

Metadata is crucial when dealing with scenarios involving Learning Objects as it represents a common understanding and a grouping of good practice guidelines when cataloguing digital files that are submitted for storage to the LOR. Metadata promotes the desirable property of Learning Object reusability as the generally understood description of resources through its various fields facilitates users from the community of practice to find and use Learning Objects for the educational scenarios of their liking.

When reuse occurs, teachers, for example, avoid the necessity of recreating an educational resource that has already been authored, widely used, catalogued, evaluated and approved inside the community. The advantages are evident because the instructor reusing the LO gained significant savings in time, effort and cost that otherwise he would have to deal with, while simultaneously profiting on potential quality enhancements from the general acceptance of the LO inside the community [12]. As McGreal [2] wisely states, "Learning Objects make it unnecessary to have thousands of iterations of the same teaching point". As for learners, metadata helps the "searching, acquisition and use" [8] of particular educational resources that might be of their interest.

So far, metadata for the purpose of being coupled alongside resources thus forming Learning Objects has been presented, but of particular interest to the users that form a community around repositories are a different kind of metadata that contribute to the overall experience with a given educational computer application. This kind of metadata is commonly referred to as Attention Metadata as systems gather automatically, silently and precisely which actions users are performing and where their attention is directed towards hence forming a context. Personalized Education tools aim to "support students during their learning process" [30] and "the first step consists in capturing the context in which they evolve" [30]. This context, that may include, for example, information that the user explicitly provides to be a member of a certain community (such as age, topics of interest ,educational background, etc) or implicit information from previous interactions with the application "is of vital importance to provide them (the users) with learning contents and teaching tactics according to their individual needs"[30]. This contextual information is used in a set of features such as personalized ranked search or Learning Object recommendations that are typically present in evolved TEL applications.

Another sensitive subject when dealing with data pertaining to the users of a learning object community is related to copyright licenses. When a particular user submits a resource to a repository it is expected in an ideal scenario that any other user can freely use that resource, modify it or integrate it in a larger granularity Learning Object for a specific learning task. This is not always the case. For instance, "when copyright owners choose to prohibit derivative works" [40] it becomes cumbersome to achieve reusability goals for a LOR. In an extreme case "when access is hindered" [40] by bureaucracies such as contracts or licenses "users just turn away" [40]. As a workaround, and according to a recent survey of McGreal on LORs, "most repositories (…) use some form of open access permission, such as the Creative Commons License" [40]. Creative Commons in the particular case of Learning Object Repositories and other Educational Platforms such as the popular MIT-OCW (Massachusetts Institute of Technology - Open Course Ware) becomes very important since it allows the use, sharing and remixing of original work as long as attribution rights are maintained (meaning a user must acknowledge the authorship of the original creator) and the Creative Commons license isn't suppressed by a more restrictive license.

2.2 Semantic Web

The challenge of the Semantic Web movement is the providence of machine readable data, semantically describing resources on the World Wide Web. As machines can work more easily over larger sets of data than humans, the potential for the emergence of applications leveraged by huge, distributed sets of machine readable data is promising [44]. When data is structured according to a vocabulary specified in RDF, resources uniquely identified by URIs and requests/responses are made on the web over HTTP, the linked data principle can be made possible by interlinking the above mentioned structured data. The end result is the possibility to make use of a structurally richer web of data by client applications with querying (through SPARQL), inferring and processing capabilities.

A renowned cataloguing achievement starting from unstructured data towards structured information, according to the semantic web and linked data principles is the DBpedia project. DBpedia aims "to extract structured information from Wikipedia and to make this information accessible on the web"[4].

Bizer et al, in [4] while describing the architecture and features of DBpedia, emphasized that their system benefits from Wikipedia's "large scale collaboration of end-users, who are not even aware that they contribute to a structured knowledge base", an example where the community effort of publishing, revising and editing of articles is skillfully repurposed towards resource cataloguing.

External client applications, besides taking advantage of the Linked Data approach, can use a SPARQL endpoint to query a knowledge base of resource descriptions. DBpedia also provides an endpoint and a knowledge base, the latter is implemented as a triplestore which warehouses entity descriptions exportable as, for example, RDF in the nTriple serialization option [44].

2.3 Personalized Ranked Search

Learners, teachers and contributors individually have their own preferences, characteristics and past experiences with a particular supportive learning tool. As so, in order to continuously adapt the learning application to the expectations of the evolving user, guidance in particular features must be personalized to an extreme extent [15]. In the scope of LORs, ranked search and LO recommendation are 2 functionalities that require an introspection process generally comprehending as input the user's profile, their past interactions with the application and the stored resources themselves (meaning LOs with their content and metadata record).

As described in section 2.1, automatically capturing user interactions with a given application results in the storage of attention metadata whose usage targets the improvement of user experience in future interactions with the application. By using attention metadata in LO ranked search or recommendation the meaningfulness of these same features towards a particular user is increased thus promoting personalization [13].

Ochoa and Duval advocate the incorporation of contextual information in ranking metrics that, individually or combined, score the learning objects meaningfully, transparently and with scalability as mentioned in their ideal scenario for LO ranking [11]. A classification of metrics was also made according to 4 types of perceived user relevance within the scope of information retrieval [11].This classification will be summarily presented as follows:

- **Algorithmic** or **System Relevance**: corresponds to how well the query terms and the resulting objects match.
- **Topical Relevance**: translates to how strong the relationship is between the returned objects and the user's topics of interest.
- **Personal Relevance**: is the association between the personal information needs of the user and the retrieved results. For example, Portuguese learners may prefer Portuguese LOs as they previously interacted more frequently with them.
- **Situational Relevance**: inflates the value (meaning the order) of retrieved LOs based on the current work task of the user (e.g. composing a collection of LOs).

Because detailing each of the metrics is outside the scope of this paper the reader can obtain their formulation in [11] and [13].

2.4 Automatic Metadata Quality Control

In an ideal scenario of labeling educational resources with metadata, either manually created by users or automatically generated by a system, one would assume that the metadata's quality is high enough so that it wouldn't require additional changes. However in a more realistic scenario, various problems arise: - submitted educational resources may not even have a coupled metadata record; - metadata records may have incomplete field values; - the resource content changed over time rendering the metadata record obsolete; - metadata field values may not properly describe the coupled resource, etc.

Metadata quality control addresses these kinds of issues as the absence of control capabilities, especially in a LOR where LO metadata is an integral part of its functions, can result in the proliferation of low quality metadata records with the potential to compromise the effectiveness of provided services. Furthermore metadata quality issues surface beyond the borders of a single LOR when integrated in a federation and when its records are harvested by other repositories [37].

The challenge with automatic metadata quality control is to accomplish 2 important criteria: - scalability, obtained by automatically calculating metadata quality by means of metrics; - and meaningfulness, where the measurements of metadata quality are highly correlated with expected human metadata quality evaluations thus being useful in the long term [37].

Ochoa and Duval in [37], resorted to Bruce and Hillmann's framework [47], which has seven quality dimensions applicable to LO metadata, to respectively define seven metrics, one for each quality dimension:

- **Completeness**: ideally all metadata fields should be filled for a single metadata record in order to not compromise the effectiveness of a LOR's search services.
- **Accuracy**: metadata accuracy addresses how well records describe the content of the object being labeled.
- **Conformance to Expectations**: tasks associated with metadata usage can be, for instance, finding, identifying or selecting a LO. It is therefore important, with respect to a given task, that the discriminative power of the textual metadata fields describing the learning material achieves high values so that just by its metadata it becomes easily distinguishable from other materials.
- **Coherence**: is the degree to which all the metadata fields of a single LO describe the same resource.
- **Timeliness**: metadata records may have their usage potential decreased through the passage of time if, for example, the content of a particular Learning Object iteratively changes and the metadata record becomes obsolete.
- **Accessibilit**y: the accessibility of metadata records concerns the degree to which the text values pertaining to the various fields are intelligibly read and understood.
- **Provenance**: it is expected in a community of practice that certain individuals manually produce better metadata records than other. This way, by taking into account the metadata annotation effort made by a member of a community in the past, whether they were good or bad, can influence the evaluation of a metadata record concerning its quality.

As translating and explaining each of these dimensions into the metrics' formulation is beyond the scope of this paper, interested reader may resort to [37] for further details.

3. Solution and Implementation

In order to plan a solution for BOAv3, it was necessary to evaluate BOAv2 along with its qualities as a LOR in a controlled manner and recognize potential features that can benefit the end users that constitute its community. For that effect, a LOR evaluation framework was devised in a series of dimensions each of them encompassing a portion of the author's related work effort which targeted not only technology that was found applicable to LORs but also good practices and success case applications in the eLearning field including peer repositories. The following subsections are therefore organized by each of the framework's dimensions, the latter can also be inspected being applied to the BOAv2, BOAv3, MACE, Connexions, MERLOT and ARIADNE LORs in table 1. For clarity purposes, an overview of the novel features of BOAv3 versus BOAv2 is depicted in figure 1.

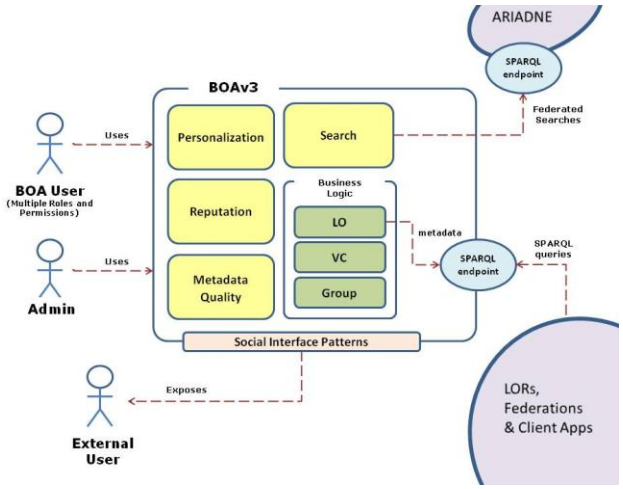

Figure 1: Solution with BOAv3's improvements versus BOAv2

3.1 General Properties

Some general properties may distinguish a repository among peers. Restricting a LOR and its objects by subject domain, coupled Intellectual Property Rights or its audience's educational background are some of the characteristics that were found to be relevant in the LOR evaluation framework.

3.1.1 Intended Audience

BOAv3 can withstand any profile of users who want to leverage their educational activities with the platform's technology in contrast with BOAv2's deployed instances, BOA-GPI and VemAprender that assume their target audiences are K12 and higher education students respectively. Moreover, with spontaneous group creation (see "Sub-Community Management" sub-section), BOAv3 delegates to the users themselves the management of who has access to a particular group therefore letting the community establish in their groups who their target audience is.

3.1.2 Subject Domain

BOA-GPI restricted the subject domain of its educational materials to pertain to the project management field of expertise. Considering group management is now delegated to community users and because LOs can be associated with groups, it is up to each group's administrators to inherently determine its subject domain by the subjects of educational resources coupled to the group. From an overall repository-wide perspective, the standardized Universal Decimal Classification system was adopted for metadata annotation purposes due to its hierarchical coverage of all fields of knowledge and symbiosis with the Dublin Core metadata scheme.

3.1.3 Federation

Although BOAv3 is not officially in a partnership with, for example, the GLOBE consortium[26], providences have been made so that, in practice, its LOs can be queried and metadata records copied over the web with its very own SPARQL endpoint. Onwards, BOA can expect increased visibility and discoverability of its educational materials simultaneously being ready and open to integrate itself in partnerships with other educational platforms as the technology to do so is deployed.

3.1.4 Intellectual Property Rights

Circumventing the possibility that educational materials may not be reused due to restrictive Intellectual Property policies is the rationale behind the decision to make BOA's LOs coupled with a Creative Commons attribution license and inherently abide to its terms and conditions. In fact, this decision's repercussions imply that the community, in order to take full advantage of BOA's capabilities, has to have the mindset of altruistically publishing learning resources free of charge with the legitimate expectation that whenever they are reused, copied, redistributed, etc, attribution rights are legally safeguarded [40].

3.1.5 Peer Reviewing

The peer reviewing capabilities of BOAv3 have been extended for a wider audience in the sense that a formal reviewing process can now have any user in the platform as a protagonist, in contrast with the previous version where only community members with the reviewer role could iteratively write a review with textual feedback whereas regular users were limited to a 5 star rating mechanism. The present reviewing process comprises not only the maintenance of the previous 5 star overall LO quality rating interface but also 3 evaluation dimensions (content quality, potential effectiveness and ease of use) which were inspired by MERLOT's approach to this matter [25].

3.2 Metadata

Metadata related dimensions address repository choices regarding which standards can be followed to describe LOs and how metadata records will be encoded in the application. The possibilities regarding the generation and quality control of metadata are also covered in their respective dimensions.

3.2.1 Metadata Standard

At development time the BOA system had a limited number of contributors and, as such, one should not inhibit those same contributors and other newcomers with an overwhelming cataloguing effort when adding Learning Objects to the repository. In this manner, the BOAv2 chosen Dublin Core (DC) metadata standard was maintained despite having the option to commit to a more expressive standard like IEEE LOM [8, 32]. For an upcoming LOR it is therefore a wiser choice to keep the simplistic and general purpose nature of the DC standard considering the expressivity versus cataloguing effort trade-off. Furthermore, DC proved itself to correlate well with both the maintenance and exposure of LO metadata with the deployed triplestore and the SPARQL endpoint respectively, since BOAv3 can be queried over the web to subsequently retrieve DC compliant RDF encodings of its stored educational resources.

3.2.2 Metadata Encoding

BOAv2 only supported XML encodings of their metadata records that can be downloaded from a specific webpage describing a Learning Object. To future proof the usage of the metadata records by client applications (e.g. other LORs), the RDF format was adopted further enhancing the LO metadata encoding possibilities of BOA[32]. Furthermore, offering a SPARQL endpoint for metadata querying has the potential to increase the probability of BOAs metadata records, and consequently its LOs, to be discovered with respect to the Semantic Web paradigm where data is shared among applications in a machine friendly format such as RDF.

3.2.3 Metadata Generation Approach

The adopted solution for BOAv3 consists in the manual annotation of educational resources, complemented with guidance and suggestions from an Automatic Metadata Quality Control mechanism (see Metadata Quality Evaluation further along this section). Despite the low scalability disadvantage and the consequent enforcement and reliance on the good will, altruism

and labor of community users to label their own submitted resources, it is expected that search mechanisms for the BOA members overall will not be compromised with poorly submitted metadata records as mentioned in [32,8].

3.2.4 Metadata Quality Control

The assumption that community users are not expert cataloguers of digital educational resources motivated the development of all the automatic metadata quality metrics of [37] whereas its application for all LOs is done on a 24 hour basis thus coping with the fact that metadata records may be created or changed through time. With the score of all metrics for all LOs in the repository calculated and at hand, an opportunity surfaces to educate the community members on how to improve their cataloguing efforts with a LO specific webpage configured with indicators to show these scores. The visualization of these indicators makes users' LO metadata annotation performance per metric intelligible whilst hovering any of them will display suggestions on how to improve their scores.

3.3 Storage

Due to the twofold nature of Learning Objects, with its components being the content and metadata record, it is important to capture this aspect in terms of storage capabilities for a LOR in the following storage type possibilities and locality dimensions.

3.3.1 Locality

Facing the LO scarcity problem, a hybrid approach was adopted by BOAv3 with respect to its locality framework dimension as LOs can be submitted to the platform by letting the users first fill in a form for metadata generation purposes and subsequently give them the opportunity to choose whether they wish to associate the newly created metadata record to either a content file hosted in the repository itself or reference an external web resource by means of its URL. By not inhibiting the referatory behavior (which was absent in the previous version), the platform, and thus the community, can benefit from the vast amount of potentially useful educational materials scattered in the web when these are formally catalogued and indexed in BOAv3 with Dublin Core, further enriching its capital of learning resources[40].

3.3.2 Type of Storage

Different types of storage systems bring forth different advantages regarding metadata.

Triplestores, for instance, are capable of delivering XML or RDF encodings of its triples (in the various serialization formats) according to the "subject-predicate-object" convention whereas if applied to a LOR these RDF encodings can correspond to the metadata records of requested LOs [7]. More concretely, if one would want to express that a certain LO has a title named "Introduction to Javascript" this would be possible by means of a triple by considering a URI uniquely identifying the LO to be the subject, the title as the predicate (given, for example, by the Dublin Core element set namespace) and "Introduction to Javascript" as the corresponding object value describing the LO [44].

Lucene is a software library supporting text indexing and searching whereas coding against its API comprehends the concept of documents whose named fields contain textual values. Mapping a metadata record's fields with Lucene document's fields makes it possible to leverage a LOR's search capabilities and retrieve pertinent LOs by matching user provided keywords with the textual values present in Lucene's indexed document fields.

Relational Databases allows applications to model their domain entities into tables, columns and rows while LO metadata may also be modeled against a relational database and associated with other stored data(e.g. application data, user data, etc) simultaneously benefitting from Database Management System features like SQL(Structured Query Language), indexing or transactions.

3.4 Search Facilities

Distinct search facilities in the following dimensions have their own traits thus accomplishing different goals for the actors who seek to retrieve learning resources.

3.4.1 Simple Search

BOA's simple search mechanism follows the recurrent LOR approach of providing a single textbox in order for the user to fill in the search query that is aligned with his expectations regarding the retrieval of LO results. Being a lightweight facility, the user is not required much cognitive effort besides the completion of the textbox in order to produce a query whose matching criterion is how well the provided words match the textual content of the LO's file or Dublin Core's title, description or subject metadata fields[8, 25, 29]. Whenever a full or partial match occurs, the user is given the possibility to verify the excerpts of text in which his query was found, along with the information regarding which DC field or text content the match was obtained from.

3.4.2 Advanced Search

With the Advanced Search feature, a BOA user can individually discriminate which metadata fields he wants his query to be matched against[25]. With this in mind, the interface is displayed so that for each DC metadata field a user control is configured to allow community members to provide the values that conjointly represent his query. When the query is submitted, the occurrence of user provided values for each of the DC fields are taken disjointly, meaning that if a value is not found in a particular stored LO's fields it will not inhibit that same LO from appearing in the search results if a match is made against another field with another value taken from the user's query.

3.4.3 Browsing

Browsing modalities are offered to BOA users in the form of tag cloud visualizations for DC's subject, format, audience and spatial coverage fields with an additional tag cloud for community member provided keywords[28]. Regardless of the tag cloud at hand, labels are sorted in a descending order implying that the most popularly used labels with respect to subject, format, etc repository-wide are presented first whilst its appearance size-wise is amplified by the recurrence of label usage which is also shown alongside the label as a number. The implementation of all the browsing visualizations was taken as an opportunity as well to expose RSS links alongside each tag cloud item so interested parties can receive updates about recently submitted or changed LOs (more on RSS further on).

3.4.4 Personalized Search

The capture of contextual attention metadata in the application became a reality in BOAv3 thus enabling the personalization enhancement of the simple and advanced search mechanisms as both are currently tailored to the current task and educational preferences of the active community member. In this manner, LOs in search results are ordered according to a score extrapolated from an individual user's past actions within the platform, hence making retrieved resources which are expected to be of his higher interest stand prominently presented in the first few positions[8, 13, 25]. In practice, following the return of the original set of

searched LOs, along with their respective base algorithmic relevance score, a custom score is further composed in a linear combination of all the personalization metrics in [11] consequently complying to the topical, personal and situational relevancies.

3.4.5 Federated Search

In order to tackle the LO "scarcity problem" typical of isolated repositories [11], BOAv3 implements a federated search service by exploiting ARIADNE's semantic web endpoint which given a SPARQL query (within the payload of a HTTP request), targeting its triplestore, returns results corresponding to LOs within the scope of the GLOBE federation. Due to ARIADNE being a referatory, meaning a LOR whose LO content is referenced by URLs, BOA users who resort to this search facility are presented with the location on the web of the LO content along with matched title and keywords properties in retrieved search results.

3.4.6 SPARQL queries

Much like ARIADNE and dbpedia [4], BOAv3 also makes available an endpoint which is symptomatic of the positive impact of storing metadata records as triples in the triplestore thus making them queryable with SPARQL alongside the ability to export those same records as RDF if desired. Although not directly targeted towards BOA's web application users but rather to external client applications or web crawlers, this search modality can leverage other eLearning platforms' search mechanisms while simultaneously exposing, with increased discoverability, BOA's educational resources to other communities in the same manner that is described in sub-section 3.4.5 with BOA federated search's reliance on ARIADNE's SPARQL endpoint. Because BOA made provisions for its LOs to be linked across the web through their URIs thus following the Linked Data approach, this search mechanism could reveal itself to be an important asset for this platform's future as learning materials are no longer exclusively obtained by humans through the web application's interface but can also be automatically processed by machines.

3.5 Social Features

Learning Object Repositories which enjoy continuous success have deployed social features that target the stimulation of their respective communities thus leveraging an increase in numbers of both LOs and new members, consequently augmenting interactions between both entities.

3.5.1 Sub-community Management

BOA's community can be taken as a whole but is not inhibited to remain static as a single unit. The application can be used to partition sub-communities whose learning goal, whatever it may be, is clear to those included in them. BOAv2 had two deployments of its application: - VemAprender targeted K12 students and educational materials; - and BOA-GPI was used as a support LOR for university students and teaching staff for semester long courses associated with the Project Management knowledge area in Instituto Superior Técnico. With BOAv3 however, by letting the users themselves spontaneously and out of their free will, create the sub-communities which they deem to be interesting can be a powerful asset for the BOA project to attract users, potentially newcomers, that otherwise may not have had a place to establish their sub-communities in. Besides surrounding a subset of community members, these user aggregates can at the same time consider yet another subset of LOs or Virtual Collections which are object of the group's work effort whichever their goal may be.

3.5.2 Virtual Collections

The BOAv3 allows its community members to create collections from the pool of available LOs in the repository which can then be converted if so desired into a higher granularity LO making it discoverable and downloadable (as a .zip file) just like any other educational material in the application. A virtual collection itself can be scrutinized by the community with reviews or have its targeted user actions syndicated with RSS as every collection in the system is subject to reputation.

3.5.3 Intra-site messaging

In order to complement the community users' communication and collaboration needs, a message center makes it possible to send intra-site text messages just like a user would send an email with the recipients, subject and message fields [3]. Besides messaging, this message center is complemented with a mechanism that lets a user keep track of notifications that concern him and might additionally require his action. For example, if a community member is invited to join a group, he is notified through the message center as the application's skin header visually shows whether there are new messages or notifications.

3.5.4 RSS (Really Simple Syndication)

RSS feeds were made available for a multitude of targets allowing interested parties to syndicate and consume the latest updates within the BOA application. Because actions targeting users, virtual collections, groups and LOs are automatically captured by the system for reputation and personalized search metric scoring purposes, they can also be retrieved chronologically ordered in a RSS feed.

3.5.5 Tagging

BOA's community can now label LOs with text suited to their own personal understanding of them thus enhancing metadata by extending the reach of educational resource descriptions to a point that is not easily achieved by solely relying on the rigid taxonomic vocabulary values of DC's properties. As such, a folksonomy of user concepts is allowed to emerge within the application providing an organization of LOs based on the frequency of community-wide used keywords which is, in turn, manifested in a social browsing tagcloud [6, 29]. Moreover, these concepts contribute to the discoverability of niches of LOs with the simple and advanced search mechanisms by enabling an additional field for the user provided query terms to be matched against.

3.5.6 Reputation System

BOAv2 adopted a credit mechanism which, in turn, represented a virtual currency. Users gained credits by positively contributing to the repository either individually or collaboratively and spent it by purchasing LOs whose price, also in credits, varied according to their popularity in a manner which is analogous to how stocks are inflated in value in their respective markets. It is doubtful that this mechanism stimulated and rewarded user engagement by the fact that the expenditure of credits invalidated the purpose of quantifying user contributions (and reputation) by their number of credits. Moreover, a user by having the obligation of having a certain amount of credits to buy the most popular and maybe the highest quality Learning Objects may find the price unreasonable and inhibiting. Given the current openness trend with respect to educational platforms and resources it was a wiser choice to give up the virtual currency facet of this credit mechanism.

In order to circumvent the limitations of the credit mechanism, a different approach towards a reputation system was adopted following the good practices suggested in [49]. At the very foundation of BOAv3's Reputation System is the capture of users'

actions against a set of 4 established reputable targets meaning learning objects, virtual collections, groups and users. Every time an action is performed in the application, they are formally indexed in the relational database clearly identifying the subject user, the target entity (LO, VC, Group or User) along with the necessary timestamp and additional contextual information if applicable (e.g. the capture of a peer review action also considers the review scores as context). Regardless of target, the reputation metrics consider a time decay function that takes into account the timestamp in an attention metadata record thus deflating the contribution of the raw action point value through time so users have a hidden incentive to consistently maintain engagement levels preventing their LOR efforts from stalling. The final reputation score feedback is made visually intelligible with gauges in the signature pages of the LO, VC and Group targets whereas the logged in user's reputation is more prominently shown in the header of the application's skin.

3.5.7 Social Interface Patterns

As an upcoming LOR, BOA demanded the development of 6 social interface patterns making provisions for a future where the platform could reach an abundance of users and an increase in LO discoverability [42, 43]. Each social interface pattern shall be presented with their respective solution and implementation details in the following paragraphs.

The **Displaying Pattern** addresses the visibility and discoverability of a LO outside of BOA's application domain. In practice, a portion of content to be exhibited as a pre-visualization can be shown in an external webpage via copy-pasting a portion of HTML markup which is found in a LO's web page.

The **Send/Share Widget Pattern** takes advantage of the massive popularity of social networks web sites like Facebook or LinkedIn to provide BOA's community users the capability to share the LOs of their liking in these platforms where they can be acknowledged by a wider audience while having the BOA brand advertised.

The **Embedding Pattern** takes into account that a user might want a particular freely available learning object to be fully shown in a third-party website, blog, etc. In practice it is the providence of a portion of markup code that when deployed on a webpage allows any web browser to interpret its meaning and present the LO's content referenced in the markup.

The **Send/Receive Invitations Pattern** addresses community growth leveraged by the acquaintances of a particular user already acknowledged in the LOR community. A formal yet personally tailored invitation can be sent by email automatically presenting the LOR, its benefits and coupled with a link directed at the site (e.g. a link for the LO, VC or group's page).

The **Profile Pattern** has been upgraded when compared to BOAv2's user presentation page with additional details regarding the user at hand. As such, users can freely present themselves with a textual biography along with their subjects of interest, country, organization or personal webpage besides the mainstream first and last name identification. A user's reputation and submitted LOs can also be conferred in the profile page giving an overall sense of what they are worth and contributed inside the platform.

The **Personal Dashboard Pattern** addresses the chosen set of functionalities, community updates, relevant events and friend subscriptions that the user must have quick and easy access as it is expected that the personal dashboard is object of repeated usage by its owner. From a particular end-user's perspective, the LOs pertaining to his user subscriptions are immediately presented in the center of the interface showing the novelties that are of potential interest to him since his last login. Moreover, every user can resort to a journal to express his thoughts towards his subscribers while reciprocally receiving a textual news feed from his community subscriptions. Expandable menus showing the LOs, VCs and Groups associated with the logged in user are also integrated in a left-sided menu with the added option to bring up a pop-up to make a new contribution with respect to the 3 mentioned targets.

4 Evaluation

A qualitative LOR framework-driven evaluation was performed with the explicit intention to determine how well BOAv3 fares against other LORs in terms of its functionalities and repository qualities. As the comparison is controlled by the LOR evaluation framework of section 3, each of its dimensions when applied to BOAv2, BOAv3, MERLOT, MACE, ARIADNE or Connexions allow for the revelation of their values and qualities as thoroughly shown in table 1. Overall and in comparison, BOAv3 not only matches but selectively surpasses other LORs in terms of available functionalities. Moreover, although some repositories may also have a particular functionality deployed within their application, BOA may hold an implementation edge which makes it more useful for community members.

Considering the "Search Facilities" higher level dimension in table 1, it can be understood that BOAv3 is the only repository that provides an implementation of every single search facility, each of which have having differing goals, usability or target audience. It should be also mentioned that personalized search is a rare asset among LORs, while BOAv3 seamlessly integrates it along the simple and advanced search mechanisms when search results are retrieved and ordered according to a linear combination of personalization metrics that, being calculated on a 24 hour basis, have as input not only the values present in LOs' metadata records but also attention metadata obtained from the implicit capture of user actions within the web application. The support for external applications to perform SPARQL queries is also unusual among LORs as only recently (March 2014) ARIADNE started to publish the values associated with LO metadata records on a HTTP queriable endpoint. With this feature, BOAv3 can have its LO metadata records consumed by client applications meanwhile having established provisions for possible future partnerships.

Metadata records themselves are evaluated in BOAv3 according to a set of metrics whose score determines a set of suggestions whose goal is to aid the end user to improve his LO cataloguing efforts. In comparison, BOAv3 along with ARIADNE are the only LORs which have a quality control feature. Implementation-wise and on a future proof perspective, the scalability of the quality control feature is assured by repeating the calculation of relevant metrics on a daily basis thus keeping up with the repository's growth in terms of LOs.

From a social features perspective, sub-community management is assured with the liberal creation of groups whose learning goal is freely determined by its user roster. Privileged group members in BOAv3 have the possibility to granularly specify with permissions who has access to the group itself hence this aspect being clearly advantageous versus other LORs which either statically partition their groups ahead of time or quite simplistically allow a small set of platform users to determine overall, and for the entire repository, who belongs in which sub-community much like in MERLOT's case.

			BOAv2	BOAv3	MACE	Connexions	MERLOT	ARIADNE
General Properties	Intended Audience		K12 (VemAprender), Higher Education (BOA-GPI)	Unrestricted	Unrestricted	Unrestricted	Unrestricted	Unrestricted
	Subject Domain		Unrestricted (VemAprender), Project Management (BOA-GPI)	Unrestricted	Civil Architecture	Unrestricted	Unrestricted	Unrestricted
	Peer-Reviewing		Present	Present(Improved)	Present	Present	Present	Not Present
	Federation		Not Present	Not Present	Present(GLOBE)	n/a	Present(GLOBE)	Present(GLOBE)
	Intellectual Property Rights		Creative Commons	Creative Commons	Creative Commons	Creative Commons	Creative Commons	Creative Commons
Metadata	Standard		Dublin Core	Dublin Core (plus location property of IEEE LOM if applicable)	MACE-AP (application profile based in IEEE LOM)	CNXML (application profile)	IEEE-LOM	IEEE-LOM
	Encoding		XML	XML, RDF	XML	XML	XML	XML, RDF
	Generation Approach		Manual and Automatic (some fields)	Manual and Automatic (some fields)	Manual (automatic enrichment)	Manual	Manual	Automatic
	Quality Control		Not Present	Present	Not Present	Not Present	Not Present	Present (Validation service)
Storage	Type		Relational DB, File Storage	Triplestore, Relational DB, Lucene Index, File Storage	Relational Database with XML exports, Lucene Index	n/a	Relational Database with XML exports	Relational (Oracle DB), Triplestore
	Locality		Content hosted locally	Hybrid	Referatory	Hybrid	Referatory	Referatory
Search Facilities	Simple		Present	Present	Present	Present	Present	Present
	Advanced		Present	Present	Present	Present	Present	Present
	Browsing		Not Present	Present	Present	Present	Present	Not Present
	Personalized Search		Not Present	Present	Present	Not Present	Not Present	Not Present
	Federated		Not Present	Present	Present	Not Present	Present	Present
	SPARQL Queries		Not Present	Present	Not Present	Not Present	Not Present	Present
Social Features	Virtual Collections		Present(Limited)	Present (Improved)	Present(Limited)	Present	Present	Not Present
	Sub-Community Management		Present	Present(Improved)	Not Present	Present	Present	Not Present
	Intra-Site Messaging		Not Present	Present	Not Present	Not Present	Present	Not Present
	RSS		Present(Limited)	Present(Improved)	Not Present	Present	Present	Not Present
	Tagging		Not Present	Present	Present	Present	Present	Present
	Reputation System		Present(Credit System)	Present(Improved)	Not Present	Present	Present	Not Present
	Social Interface Patterns	Displaying	Not Present	Present	Present	Not Present	Not Present	Not Present
		Send/Share Widget	Not Present	Present	Present	Present	Present	Not Present
		Embedding	Not Present	Present	Not Present	Not Present	Not Present	Not Present
		Send/Receive Invitations	Not Present	Present	Not Present	Not Present	Not Present	Not Present
		Profile	Present(Limited)	Present(Improved)	Present	Present	Present	Not Present
		Personal Dashboard	Present(Limited)	Present(Improved)	Present	Present	Present	Not Present

Table 1: LOR Evaluation Framework applied to BOAv2, BOAv3, MACE, Connexions, MERLOT and ARIADNE

Monitoring and rewarding community members for their altruistic behavior is assured by an improved reputation system which, unlike BOAv2, does not restrict access to the repository's educational materials based on a virtual currency. Moreover, reputation is calculated for a series of targets, i.e. LOs, VCs, groups and users, whereas its scores are made visually intelligible with properly placed gauges in the UI. All of this contrasting with the approach taken by other LORs that are either limited in the number of actions (Connexions only considers LO viewing actions to measure popularity) or do not take into account user engagement levels with a time-decaying function applied to reputation levels.

BOAv3 also uniquely distinguishes itself among peer repositories by implementing all social interface patterns that are proven solutions to trigger social and collaborative behavior in the community members further allowing LOs, VCs or groups to be visually exposed outside the context of the BOAv3 domain with either HTML overlays in blogs, shares on social networks, embedded content on web pages or even emails.

Table 1 discriminates for each LOR in the columns and for each of the framework's evaluation dimensions in the rows all the repository qualities in their respective cell.

5 Conclusion

As eLearning is driven by the evolution of technology when applied to this particular field of knowledge, all interested parties who seek to leverage their educational activities gain significant profits in being assisted by applications which have been proven to have a positive impact not only in a pedagogical sense but also in time, effort or even monetary savings. With this in mind, learners or instructors, for example, may have a need to find learning resources in the World Wide Web to complete their tasks whether they are meant for self-learning purposes or for the reuse and assembly of other higher granularity learning resources. To accomplish these scenarios, Learning Objects were introduced as digital educational files that while being coupled with a metadata record have its content described in a standardized, controlled manner. Learning Object Repositories, on the other hand, are web applications whose scope of responsibilities includes the indexing of LOs and the providence of search mechanisms for users to find, share or reuse the educational resources they need.

Ideally, a successful LOR has an abundant, giving and engaged community of members, an abundance of properly catalogued, referenceable and easily discoverable materials and a deployed set of personalized functionalities which can be exploited by any user to successfully complete the goals of any conceivable learning task. However, realistically and furthermore for up and coming LORs like Bolsa de Objectos de Aprendizagem, it is a difficult challenge to achieve that ideal scenario. For BOAv2 to evolve towards its third iteration it had to be initially evaluated qualitatively in a controlled manner in order for its shortcomings to emerge so a solution can be specified, subsequently implemented and the resulting impact assessed. To evaluate BOAv3 a LOR evaluation framework was devised in a series of dimensions each of them encompassing a portion of the author's related work effort which targeted not only technology that was found applicable to LORs but also good practices and success case applications in the eLearning field including peer repositories. The application of the LOR evaluation framework projected a possible solution for BOAv3 which comprises the features summarily described in the following paragraphs.

Offering various encoding options, particularly RDF, and exposing the metadata records through a queriable SPARQL endpoint increases the possibility that BOA's LOs will be discovered both by client applications and federations of LORs alike.

Providing a quality control feature for metadata records and suggesting possible improvements to users cataloguing learning resources identifies problematic records, educates the community, reduces the chance that low quality records are proliferated and helps search services that rely on metadata to perform well.

Reaching an abundance of LOs is partially solved by exploiting the federated search services offered by other LORs (e.g. ARIADNE). The retrieved external LOs can be presented to BOA's users as they will more consistently find and navigate to the educational resources they were looking for by means of its URL. BOAv3 itself can have metadata records referencing content hosted elsewhere on the web exhibiting a referatory behavior improving, at the same time, the perception of BOA's utility as a repository.

Capturing individual user's actions within the application creates an opportunity to reward them accordingly for their time and effort from a community's recognition point of view. Simultaneously, engagement levels are maintained and contributions encouraged by means of a dedicated and scalable system which automatically scores the reputation of LOs, VCs, groups and users through time. Educational materials, meaning LOs, can also be explicitly and manually targeted for a valued judgement with peer-reviews.

Applying social interface patterns triggers social collaborative behaviors in the community keeping users interested in the repository and assures the possibility of showing LOs outside the BOAv3's domain (e.g. in widely popular social networks) eventually attracting newcomers with personalized friend invitations. Users can also articulate their activities by messaging their fellow community members.

Users can freely collaborate in community partitions in the form of groups with the capability to granularly control its access and visibility with permissions. Groups' learning goals are inherently determined by its constituents by further allowing this entity to be associated with LOs and VCs which are chosen according to the discretion of a set of privileged group users.

Users' educational interests and needs are taken into account with personalized simple and advanced search features which automatically orders retrieved LO results by means of a linear combination of scores stemming from a set of personalization metrics that take into account past user actions within the BOA application in conjunction with data in metadata records. As such, relevant search results for each individual user are prominently shown at the top of the retrieved LO listings.

The work effort behind the development of BOAv3 generated some insights which can become invaluable for the eLearning research community or educational software designers and developers alike, specifically those looking to improve a Learning Object Repository or develop it from scratch. In this sense, the developed LOR evaluation framework, although not definitive and subject to refinements, can easily be applicable to this kind of applications and moreover constitute an important reference tool to not only identify possible shortcomings but also to understand the implications and tradeoffs of every decision for the community at hand, the LOs themselves and external entities (eventually other LORs) that may find an interest in the platform.

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