Metrics for Learning Object Metadata

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Abstract. Previous research has set the foundation of Learning Object Technologies; unfortunately just the foundation is not enough to convince instructors and learners to use the technology. Mature tools are needed in order to breach the early-adopter - mainstream gap. Following what has been done with other related technologies, this work presents research to create automated measurements (metrics) that could enable the creation of a new generation of smarter and friendlier learning object applications. The methodology for the proposal and test of the metrics is discussed, along with early encouraging results in the area of metadata quality metrics. Finally we present possible applications of the current and future results of this research.

1. Research Context and Justification

During almost 15 years of research, the foundation of Learning Objects Technologies has been set. There are standards that define the metadata that describe a learning object [1] and how to sequence it [2]. Thanks to these standards, Learning Management Systems (LMS) are able to import and export learning objects of different granularity. There are several repositories worldwide where the instructors can publish the learning objects that they create and search for learning objects published by peers [3]. Thanks also to standardization [4], these repositories can query each other and present the user with a considerable amount of results.

Despite all the development in this necessary foundation, the tools that the end user access to index, search, integrate and re-use learning objects are still immature if we compare them to similar tools used in related fields. For example, web pages creators or papers publishers do not need to manually index their work [5] [6]. The basic text-matching or field-matching techniques of current learning object search tools are not enough to sort the huge amount of results returned by federated queries, a problem that has been solved in the World Wide Web thanks to PageRank-like algorithms [7]. There is not readily available equivalent in the learning object community for the Amazon’s book recommending feature [8]. This lack of maturity is reflected in the low level of adoption of learning object technologies among instructors and learners [9] [10].
In order to improve the adoption of learning object technologies, smarter and friendlier end user tools must be developed. These tools should capitalize the vast amount of information that is present in the learning object metadata and other sources as context and usage. To be exploitable, that information should be automatically measured and processed to extract deep knowledge of the characteristics, relations, usefulness, behavior and recommended usage of individual learning objects, as well as, complete learning object repositories. This research will create and test automatic quantitative measurements (metrics) for learning object metadata. The objective of the metrics will be to find useful calculations that use intrinsic and extrinsic information to improve the performance and usability of the current tools. For example, if the number of times an object is reused (metric) is a good predictor of the relevance of a learning object (learning object characteristic), it could be used inside the sorting algorithm of federated search application (tool). We have called this initiative “Metrics for Learning Object Metadata”.

The idea of using metrics to automate or improve tools or procedures has been borrowed from other fields: Software Engineering uses metrics to semi-automatically determine the cost and duration of software projects [11]. Scientometrics creates metrics to automatically predict the “impact” of a journal or gain insight about the research environment at a given moment and field [12]. Webometrics creates metrics to determine the relevance of a web page [13] (for example Google’s PageRank metric [7]). This new small research area, Metrics for Learning Object Metadata (Learnometrics), will create metrics based on the information present in the metadata record(s) of a learning object and the contexts where it is used to enable the creation of a new generation of Learning Object end user tools.

2. Research Focus

During this research work, we will create and test metrics for three main areas:

Quality of Metadata:
The quality of the metadata record that describes a learning object affects directly the chances of the object to be found, reviewed or reused [14]. To deal with the exponential grow of metadata records available and at the same time to be able to retain some sort of quality assurance for the information contained in the metadata record, we propose automating the quality assessment of learning object metadata. This automated evaluator will assess intrinsic characteristics of the metadata itself, measured through the use of one or more synthetic metrics.

Similarity between Learning Objects:
We propose to measure the semantic distance between two or more learning objects. This metric (or set of metrics) will enable the creation of a service that can automatically cluster two or more learning objects together based on their characteristics. All kind of tools, from Automatic Metadata Generation to Recommendation Systems, can use this service to improve their performance.
Relevance of Learning Objects:
This group of metrics should give insight on the relevance of learning objects in a specific situation based on the available information from the learning object metadata, usage and context information, as well as, users’ annotations. These relevance metrics could be the seed to create a LearnRank [15] algorithm.

3. Methodology
Finding useful metrics is an experimental endeavor. A lot of try-and-error is needed to find good predictors. First, (1) based on theoretical or empirical considerations, a metric is proposed. Then, (2) an experiment is set-up to obtain a real value for the characteristic we want to predict with the metric. Finally, (3) the real values are compared with the values obtained from the metric. If the values correlate for different learning objects or users, then the proposed metric (or metrics) is (are) a good predictor for the selected characteristic. This metric could then be use to provide services to improve a tool (4).

As an example of this procedure: (1) The set similarity theory will suggest that counting the number of fields where two learning objects have the same value could be used to predict how similar they are. (2) The experiment will be to present a set of different learning objects to a group of human examiners. They will score the grade of similarity between them. (3) The scores will then be correlated with the values calculated with the similarity metric for the same objects. As result we will know if the similarity metric is a good predictor of the similarity as perceived by human reviewers, and (4) we can use it inside a learning object clustering service.

To facilitate this experimentation, a framework is being built. This framework, called M4M, enable easy prototyping of metrics and tests against real data. While M4M has been developed for learning object metadata it is based on a XML database, in this way, it could be easily extended to support any other kind of metadata.

4. Current Status
At the time of writing, the most developed research field is Metadata Quality Metrics. We have developed a group of interesting metrics to assess the quality learning object metadata records, loosely based on a metadata quality framework proposed in [16]. In an accepted paper [17] we describe these metrics and their rationale. The formula of this metrics can be seen in Table 1. These metrics has been tested against the quality value obtained from an online experiment were human reviewers grade the learning object metadata using the same quality framework in which the metrics where based. The results obtained indicated that one of the metrics, the Textual Information Content provide a good predictor (correlation factor = 0,842) of the evaluation of average score given by human reviewers to the evaluated objects.
Table 1. Formulas of the Quality Metrics

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<th>Metric Name</th>
<th>Metric Formula</th>
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| Simple Completeness  | \[
\sum_{i=1}^{N} P(i) \]
Where \( P(i) \) is 1 if the \( i \)th field has a non-null value, 0 otherwise. \( N \) is the number of fields. |
| Weighted Completeness| \[
\frac{\sum_{i=1}^{N} \alpha_i \cdot P(i)}{\sum_{i=1}^{N} \alpha_i} \]
Where \( \alpha_i \) is the relative importance of the \( i \)th field. |
| Nominal Information Content | \[
- \sum_{i=1}^{K} \log(P(\text{value}_i)) \]
Where \( K \) is the number of nominal fields. \( P(\text{value}_i) \) is the probability of a value of the \( i \)th nominal field. |
| Textual Information Content | \[
\log\left(\sum_{i=1}^{N} \text{tf}(\text{word}_i) \cdot \log\left(\frac{1}{\text{df}(\text{word}_i)}\right)\right) \]
Where \( \text{tf}(\text{word}_i) \) is the term frequency of the \( i \)th word, \( \text{df}(\text{word}_i) \) is the document frequency of the \( i \)th word. |
| Readability          | \[
\frac{\text{Flesch(title & description_text)}}{100} \]
Flesch(description_text) is the value of the Flesch index for the text present in the title and description of the record. |

This metric (Textual Information Context) has been used in a tree-map visualization tool where the quality of the metadata present ARIADNE repository can be easily assessed. Figure 1 present a snapshot of this application: red represents low quality metadata records, yellow medium quality metadata records and green high quality records. The size of the box represents the number of metadata records that has been created by a given author in a given local repository. This tool can be accessed online at [18].
Currently, we are using the Textual Information Content metric to compare the quality of several learning object repositories members of the GLOBE consortium [19]. In the field of Similarity Metrics, just early experiments have been performed. A clustering search application can be accessed at [20]. It clusters learning objects based on the text that is contained in the title and description fields of the metadata record.

### 4. Expected Results and Application

As a result of this research work, it is expected that several useful metrics has been found and can be used inside learning object tools in order to provide a smarter interaction with the final user. The indirect desired effect is that learning object tools become mainstream among instructors and learners worldwide.

As for the possible applications that we envision this metrics will enable, we can list a few:

- **Automated Evaluation of Quality:** To establish if the information available in the metadata record makes the object useful inside a certain application.
- **Ranking of Objects:** To assign a comparative value to an object in the result list of a search tools reflecting the relevance of the object.
• **Replacement or Updating of Objects:** To find similar, more recent/available, objects based in the characteristics or use of the original one.

• **Recommendation:** To establish the relevance of an object to an user based on usage patterns and user profiles (for example the information extracted from Social Software or Learning Management Systems).

• **Measuring the impact of Learning Objects:** Calculating how useful a learning object has been to a certain community.

• **Interoperability:** To find semantic-corrective calculations that will enable the exchange of information between two or more collections with different cultures.

4. Conclusions

As well as Webometric research lead to the development of smarter Web Search Engines, if we want to develop better learning object tools we must research about the basic characteristics of the learning object information (metadata, usage, context) and provide ways in which this characteristics could be measured and used. A new field, Learnometrics, should be researched. This work is a step in that direction.

As with the development of metrics in other fields, this task is mainly based on extensive experimentation. While this work focus on the finding of metrics in three main fields (Quality, Similarity and Relevance), it also set a methodology to explore new areas where metrics could be used to extract useful information to be used in novel tools.

This work is complementary to recent learning object research. It will consume information from Attention Logging [21], Federated Searches [4] and Social Networks and will provide services that can be used by Adaptive Learning, Social Recommending [22], Automatic Generation of Metadata [23] or Visualization [24] applications.

References