Quality Metrics in Learning Objects

Juan F. Cervera, María G. López-López, Cristina Fernández, Salvador Sánchez-Alonso

Abstract. In today's rapidly evolving society, the range and depth of information available to us is quickly growing which affects educational institutions, who find it difficult to keep their programmes up to date, whilst students struggle to find the right information. The paradigm of learning objects is an emerging technology aimed towards facilitating the managements of the massive amount of (educational) resources available. Enabling users relying on this paradigm to use concise and high quality pieces of knowledge within different contexts represents a key challenge. Therefore, when designing learning objects, reusability must be a key consideration. Bearing this in mind, the current lack of metrics to help measure quality and reusability represents a major issue. Specific metrics for learning objects will eventually appear, probably based on extended and improved metadata. In the meantime, there remains the need to measure the potential reusability of the existing base of learning objects. This paper attempts to bridge this gap by analysing and developing adapted metrics for learning objects, based on existing metrics used in other disciplines such as software engineering.

1 Introduction

This paper extends the theoretical framework proposed by Cuadrado in his paper about learning object reusability metrics [1], which explores the possibility of using existing metrics, such as Chidamber and Kemerer Object Oriented metrics [2], and adapting them to the domain of learning objects (LO).

Juan F. Cervera
Information Engineering Research Unit, University of Alcalá, Alcalá de Henares, SPAIN, jfcervera@gmail.com
María G. López-López
Centro de Investigación en Sistemas de Información (CISI), Escuela de Computación, Facultad de Ciencias, Universidad Central de Venezuela, Caracas, Venezuela, lopezgertrudis@gmail.com
Cristina Fernández
Information Engineering Research Unit, University of Alcalá, Alcalá de Henares, SPAIN
Salvador Sánchez-Alonso
Information Engineering Research Unit, University of Alcalá, Alcalá de Henares, SPAIN, salvador.sanchez@uah.es

The objective of this paper is to show how we adapted, applied and tested statistically some of the metrics proposed in [1] to LOs. The purpose of this exercise was to see if these adapted metrics could provide useful results about reusability and quality of LOs, by means of correlations between the metrics and metadata. The metrics we adapted and tested were as follows: Weighted Methods per Class (WCM), Depth of Inheritance Tree (DIT), Response for a Class (RFC), Coupling Between Objects (CBO) and Lack of Cohesion on Methods (LCOM).

In order to check whether the metrics performed consistently across different knowledge areas, they were applied to two random samples of LOs selected from the Merlot repository 1; one for Computer Science LOs and another one for Biology LOs. The metadata fields used were size in bytes, granularity, number of links, peer review average (Merlot-exclusive), and member comments average (Merlot-exclusive).

2 Adapted Object-Oriented metrics

Object Oriented Software engineering techniques have been a source of influence on the design of LOs [3] [4]. In this sense, LOs can be considered particular software pieces oriented towards human interaction. Some metrics developed in the context of Software Engineering, which work with concepts such as dependency and complexity, may have a clear correlation with LO technology [1]. The original Chidamber and Kemerer Object oriented (OO) metrics to measure reusability [2] needed to be adapted before they could be used with LOs. This section explains the adaptation of each metric that we used.

2.1 Weighted Methods per Class (WMC)

The definition of this metric, according to [2], is as follows: “WMC relates directly to Bunge's definition of complexity of a thing, since methods are properties of object classes and complexity is determined by the cardinality of its set of properties. The number of methods is, therefore, a measure of class definition as well as being attributes of a class, since attributes correspond to properties”. The approach taken in [1] to adapting this metric for LOs is as follows: “The resulting metric for learning objects would be consistent with the current consideration that only learning objects of “fine granularity” may offer a high degree of reusability”.

One of the IEEE LOM metadata fields is the *aggregation level* of the LO, which is based on the granularity of the LO and measured on a scale from 1 to 4, 1 being the smallest level of aggregation and 4 the largest level of granularity. We have used this value for the adapted WCM metric.

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[1] http://www.merlot.org

2.2 Depth of the Inheritance Tree (DIT) / Response for Class (RFC)

According to [2], DIT is defined as follows: "Depth of inheritance of the class is the DIT metric for the class. In cases involving multiple inheritance, the DIT will be the maximum length from the node to the root of the tree." The definition for RFC is "The response set of a class is a set of methods that can potentially be executed in response to a message received by an object of that class".

As explained in [1], "Inheritance depth as a driver for increased complexity applies in a similar way to LOs, since subtyping entails the requirement of more detailed metadata elements".

As subtyping applied to LO is still in the early stages, the right kind of information for calculating a DIT metric is, unfortunately, not available in the metadata. Therefore, most existing learning objects will never contain this information.

The approach we have used consists of checking the depth of the links of a LO, as this information is available in the current metadata. This approach keeps the original idea of Depth and, as it is applied to links and it also resembles concepts from the RFC metric.

2.3 Coupling Between Objects (CBO)

The definition given for this metric, according to [2] is "CBO for a class is a count of the number of other classes to which it is coupled". In [1], Cuadrado argues that this metric can be directly applied to a LO's relationship with other LOs and can be defined with current metadata.

Therefore, we have adapted this metric by checking the coupling of a LO with other LOs. Had LOM metadata been available, this information could have been extracted from the relation metadata field. As it was not, it has been calculated manually. Every link to a different LO was counted towards the value of the metric; LOs with no links to other LOs were given a value of 0 for this metric.

2.4 Lack of Cohesion on Methods (LCOM)

The definition of this metric according to [2] is "The LCOM is a count of the number of method pairs whose similarity is 0 (i.e. $\sigma()$ is a null set) minus the count of method pairs whose similarity is not zero. The larger the number of similar methods, the more cohesive the class …". In [1], Cuadrado reasons that "… it can be stated that learning objectives [..] can be regarded metaphorically as attributes of the class. In consequence, disparateness of objectives [..] are indicators for ill-defined objectives, which hampers reuse".

Consequently, this metric was adapted by checking whether the objectives/subjects of a LO were concrete enough, or whether it was possible to split the LO into several, more concrete LOs. The metric was measured by the number of different objectives that could be extracted into smaller LOs, being 0 when a single educational objective was covered.

3 Analysis and results

To analyse the aplicability of existing OO metrics to the LOs domain, we run correlations between the adapted metrics and empirical metadata. As previously said, part of this data has been obtained from the Merlot repository, while the remainder was calculated by hand.We have selected two groups of 25 LOs from two different knowledge areas: Computer Science and Biology. The LOs have been randomly selected from theMerlot repository. The metadata obtained and calculated for each LO was as follows:

- Title: The title of the LO
- URL: The URL of the LO
- WCM: The results of the adapted WCM metric
- DIT/RFC: The results of the adapted DIT/RFC metric
- CBO: The results of the adapted CBO metric
- LCOM: The results of the adapted LCOM metric
- Size: Size of the LO in bytes
- NL: Number of links
- PR: Peer reviews average from the Merlot repository
- MC: Member comments average from the Merlot repository

In this section we present the correlations obtained between the metrics and the metadata using three different correlation coefficients: Pearson's correlation coefficient (P), Kendall's tau-b coefficient (K) and Spearman's rho coefficient (S). Table 1 shows the correlation coefficients obtained in the Computer Science group, where we found significant correlations between the CBO metric and the Number of Links at the 0.01 level for all types of correlation. We also found a significant correlation level of 0.05 between the LCOM metric and the Number of Links, but only for the Pearson correlation.

[1] http://www.merlot.org

Table 1. Pearson, Kendall and Spearman Correlation results obtained in LOs of Computer Science.

	Size	NL	PR	MC
WMC	P=-0,179	P=0,209	P=0,096	P=0,209
	K=-0,165	K=0,237	K=-0,005	K=0,237
	S=-0,190	S=0,279	S=-0,002	S=0,279
DIT/RFC	P=-0,056	P=0,074	P=0,293	P=0,011
	K=0,043	K=0,168	K=0,177	K=-0,091
	S=0,042	S=0,218	S=0,205	S=-0,123
CBO	P=0,160	P=0,963**	P=0,158	P=-0,199
	K=0,261	K=0,879**	K=0,281	K=-0,123
	S=0,334	S=0,961**	S=0,359	S=-0,163
LCOM	P=0,102	P=0,635*	P=-0,153	P=0,058
	K=0,110	K=0,297	K=-0,032	K=0,049
	S=0,159	S=0,354	S=-0,039	S=0,049

- P: Pearson's correlation coefficient
- K: Kendall's Tau-b correlation coefficient
- S: Spearman's rho coefficient

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Table 2 shows the correlation coefficients obtained for the Biology group, where we obtained significant correlations between the WCM metric and the Number of Links at the significance level of 0.01 for the Kendall and Spearman correlations and at the significance level of 0.05 for the Pearson correlation. We obtained correlations between the CBO metric and the Number of Links at the 0.01 level in all correlation types. We also obtained significant correlations between the CBO metric and the Peer Reviews Average at the 0.01 level for the Kendall and Spearman correlations and at the 0.05 level for the Pearson correlation.

Table 2. Pearson, Kendall and Spearman Correlation results obtained in LOs of Biology.

	Size	NL	PR	MC
WCM	P=0,278	P=0,497*	P=0,215	P=0,303
	K=0,280	K=0,524**	K=0,117	K=0,278
	S=0,342	S=0,634**	S=0,143	S=0,317
DIT/RFC	P=0,017	P=0,189	P=0,204	P=0,104
	K=0,010	K=0,272	K=0,265	K=0,060
	S=0,031	S=0,371	S=0,343	S=0,084
CBO	P=0,075	P=0,633**	P=0,448*	P=0,186
	K=0,211	K=0,633**	K=0,449**	K=0,109
	S=0,224	S=0,784**	S=0,549**	S=0,138
LCOM	P=0,026	P=0,297	P=0,281	P=0,021
	K=0,104	K=0,270	K=0,179	K=-0,005
	S=0,151	S=0,343	S=0,208	S=-0,007

- P: Pearson's correlation coefficient
- K: Kendall's Tau-b correlation coefficient
- S: Spearman's rho coefficient

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

4 Conclusions and future work

The correlation data calculated shows that the CBO metric has a strong correlation with the metadata Number of Links. As the adapted CBO metric is based on the number of links to other LOs, this result was expected.

The CBO metric has a less strong but, nevertheless, noticeable correlation with the Peer Reviews Average metadata for the Biology group only. The LCOM metric displays a noticeable correlation with the metadata Number of Links for the Pearson's coefficient in the Computer Science group only. If we consider that LOs covering several objectives are more likely to have additional links to access every objective, we would have expected a stronger correlation with this metric.

The WMC metric displays a strong correlation with the metadata Number of Links for the Biology group only. The DIT/RCF metric does not display any particular correlation with any metadata.

With the exception of the CBO metric in the Biology group, there are no strong correlations between any of the other metrics and the Peer Reviews Average metadata, nor between the metrics and the Member Comments Average metadata. Taking into account that these fields provide a measure of the quality of the LO based on evaluation by experts and end users, ideally we would look for stronger correlations between the metrics and these two metadata. This result suggests that the Peer Reviews Average and Member Comments Average metadata in the Merlot repository do not consider the reusability of LOs.

Taking into account the lack of strong correlations based on this analysis alone, we feel that further work along these lines could yield more conclusive results. However, it is important to stress that there are no theoretical requirements to have strong correlations between metrics and LO metadata. Therefore, the lack of strong correlations should not necessarily be taken as an indicator of metric validity.

In summary, we feel that we need to broaden the study scope to encompass a greater number of metrics, a larger number of LOs and an additional number of statistical and empirical tests, which should be applied to a greater number of knowledge areas, in order to prove whether using metrics borrowed from other areas of software engineering can be applied to LOs.

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[1] http://www.merlot.org

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