Metadata for Serious Games in Learning Object Repositories

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***Abstract*— In this paper, we describe the special challenges that educational games (also known as serious games) pose for online learning object (LO) repositories. As in all metadata, a tension exists between descriptive power and the effort needed to create these descriptions. This tension is even greater when describing complex, highly interactive multimedia content such as serious games. We consider serious games as LOs, proposing game-specific metadata, and advocate for game authoring tool support that streamlines its creation.**

***Index Terms*— Game metadata, learning objects, educational games, serious games, learning object repositories.**

I. Introduction

THE current technological revolution, together with the growing availability of ubiquitous, instantaneous communications, is in the process of transforming education. In educational institutions worldwide, students are increasingly dependent on technological platforms to interact with content, their colleagues and instructors. Several initiatives, such as the Open Education Consortium (http://www.oeconsortium.org/), contribute to the proliferation, sharing and availability of high-quality contents to drive educational technology adoption in these institutions. One of the key aspects of this computer-assisted learning is that of content *reuse*, through reusable educational objects (so-called Learning Objects, or LOs). Once created, LOs can be used by any number of students at a very low marginal cost (essentially zero). Due to the high cost of quality LO creation, reuse is not only desirable, but also critical to justify and amortize LO authoring.

However, effective reuse requires a large degree of standardization for LOs, and other measures directed towards simplifying and streamlining search and evaluation of the most adequate LOs for a given educational need. LO repositories allow authors to publish both LO and associated information (metadata) directed towards simplifying their categorization, search and evaluation – critical steps towards effective reuse by other educators. Thanks to metadata, these repositories can offer search tools that match (metadata-driven) queries with the most adequate LOs. Researchers have devoted significant effort to develop effective and efficient metadata for LO categorization (and later search & retrieval), resulting in a multitude of competing and complementary standards and recommendations. Standards are available for static documents, multimedia, exercises, and even complex lessons which combine several of these components and can adapt to student profiles and actions.

The present work focuses on the requirements of a type of OA which, until recently, has received very little attention from the point of view of metadata: educational games (also known as *serious games* or *applied games*). In none of the general LO repositories analyzed as part of this game is there any specific support for game metadata; this is hardly surprising, given the low fraction of the total LO count comprised of games when compared to their total volume.

However, highly-interactive multimedia content, such as games, presents significant challenges for metadata description. In effect, metadata to describe complex content needs to be comparatively more complex than that used for simple content, in the sense that simple content can be evaluated much faster even in the absence of metadata than complex content. Metadata is more important the harder it is to perform a cursory visual evaluation of whatever it is describing. On the other hand, there is always a tension between the quality of metadata for a given LO and the time and effort required to generate and update such metadata. This is why the present proposal includes elements targeted at partially automating the process of metadata generation, which we expect to result in more (and better) metadata for applicable LOs.

Section II provides background on the characteristics of games when used as LOs, and presents several examples of metadata for games packaged as LOs in the main open educational resource (OER) repositories, describing the main challenges posed by general LO reuse. Section III is centered on the specific challenges faced by game metadata, and presents several approaches to automate game metadata authoring, together with experiments which would allow validation of our proposals. Finally, Section IV contains conclusions and describes future work.

II. Games as Learning Objects

Games can be powerful educational resources. Playing is a natural way of learning, and has proven positive effects not only in retaining attention, but also in motivating students.

Manuscript received January 13, 2016; revised March 17, 2016; accepted March 28, 2016. Date of publication May 20, 2016; date of current version June 1, 2016. This work was supported in part RIURE Network through the Program Ciencia y Tecnología para el Desarrollo under Grant 513RT0471, in part by the eMadrid Program, Madrid Region, under Grant S2013/ICE-2715, in part by the Complutense University of Madrid under Grant GR3/14-921340, in part by the Spanish Ministry of Education under Grant TIN2013-46149-C2-1-R, and in part by the European Commission through Grant H2020-RAGE 644187.

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Digital Object Identifier 10.1109/RITA.2016.2554019

Motivation effects have been observed not only when games where compared with traditional lectures, but also with other types of digital interactive contents [1].

From a point of view of Virtual Learning Environments (VLEs, also known as Learning Management Systems or LMSs), games can be considered similar to other multimedia, interactive LOs: they have similar requirements from the point of view of hardware, bandwidth/connectivity, and storage; and their internal complexity in terms of the multiple paths that the game logic allows players to take can be emulated (at least in theory) by complex educational modeling languages such as IMS Learning Design [2].

However, unlike other multimedia contents, games exhibit integration of multiple media, quick user feedback, and greatly increased immersion, which combine to produce a totally different experience:

- During play, *interaction mechanics* between the student and the learning environment are completely replaced. Where the students interacted with traditional web-page controls, they can now find themselves guiding "their" character through the corridors of a hospital, or choosing the best responses to a simulated dialogue elicited by a computer-controlled character.
- Games can provide rich *narratives*. Beyond isolated hypothetical scenarios, students can see themselves immersed in an ongoing story that changes depending on their actions, incrementing the game's *replayability* value. Such an *immersion* promotes situated learning.
- Games can be significantly more *interactive* than other educational contents. This has the added consequence that they can generate large quantities of interaction data on which Learning Analytics (LA) systems can be populated and exercised, potentially allowing finer-grained assessment and student outcome prediction and/or remedial actions.

Metadata used to describe traditional content can be applied to games, with the proviso that the above points (interaction mechanics, narrative, replayability, immersion, and interaction data & analytics) would not be adequately covered.

A. Metadata, Reuse and Learning Objects

The use of standard metadata allows greater interoperability between LO repositories. The most popular metadata standard is IEEE's Learning Object Metadata [3] (LOM). In LOM, the data model specifies what aspects of LOs must be described, using 9 categories with around 70 fields; and, for some of these fields, describing the specific vocabularies that must be used for such descriptions. While the LOM standard is certainly complex, all of its fields are optional, so that in practice "application profiles" are used to specify which elements and vocabularies are relevant for particular communities of practice. For instance, UK-LOM Core is an application profile that describes recommended usage for higher education in the UK, while LOM-ES was developed for use by the Spanish educational community. Other metadata standards are much simpler: Dublin Core [4] only has 15 fields in its basic incarnation, compared to the typical 50 fields found in LOM-annotated LOs. Not all metadata elements are equally complex. In the case of LOM, the "classification" category is much more complex than, say, the "author" field found in Dublin Core.

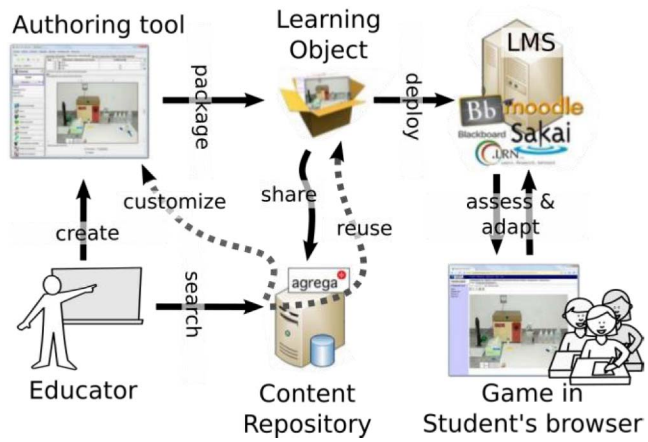

Fig. 1. Lifecycle of a game used as a Learning Object (LO): created by an educator, packaged with metadata, and distributed through a Learning Management System (LMS) such as Moodle or Sakai, to be finally displayed in a student's browser. Ideally, other educators will find it in the LO repository and reuse it.

Multiple institutions worldwide maintain LO repositories. Many of them are federated in GLOBE, the Global Learning OBject Exchange. GLOBE members include the repositories of the ARIADNE Foundation [5] (European Union), MERLOT [6] (California State University) and FLOR (LACLO, of Latin-American scope). A study by Ochoa et al. [7] on nearly half of the 1.2 million of GLOBE's LOs (in 2011) revealed that only 20 of the $\sim$70 LOM elements were consistently present, including only 4 of the 11 educational elements. Ochoa et al. also described patterns of tagging and metadata authoring that differed markedly according to authoring community and source repository.

B. Games in Learning Object Repositories

Metadata are used to describe LOs before adding them to repositories. Generally, metadata is added at the end of the authoring phase, by the authors themselves. Metadata will hopefully allow other educators to later find the LO in a repository in response to their queries (see Fig. 1). For example, the authors of the current work maintain the serious game platform eAdventure, which allows, through its game authoring environment, packaging with IMS-CP, LOM and LOM-ES metadata [8], and has additional specific support for LAMS and the AGREGA [9] repository.

Many repositories already contain educational games. Of varying size and complexity, they currently represent very small fractions of the total repository size. Table 1 provides counts of results when searching for LOs of type "game" and "simulation" (and their Spanish translations) in AGREGA/PROCOMUN [10], [11], ARIADNE and MERLOT. Although many simulations can be considered almost games in their own right, distinguishing between both would have required a case-by-case analysis, which was

TABLE I
GAMES IN MAJOR LO REPOSITORIES

Type of LO	ARIADNE	MERLOT	PROCOMUN
All	830297	44901	70598
Games	0.25% (2092)	N/A	0.43% (303)
Simulations	0.72% (6002)	7.75% (3480)	0.19% (137)

(As of May 2014)

considered out of scope for the current paper. For example, a small physics-based simulation of planetary orbits can be considered a game on its own right (if meshed with a supporting background story or some other kind of narrative which requires the player to manipulate these orbits) – or as a simple interactive plot of the ellipses that result for a set of initial orbital parameters. In the case of MERLOT, there is no separate "games" category, although a cursory analysis of a small sample of LOs classified as simulations reveals several that could be considered games according to the above criteria. Surprisingly, the relative number of games/simulations in MERLOT is a full order of magnitude larger than that found in ARIADNE and PROCOMUN, none of which exceed 1%.

On the other hand, there are several repositories that specialize in games (although in general without considering them as LOs). For instance, ClarkChart [12] contained, in May 2014, over 200 games and simulations; while the Serious Game Directory [13] listed over 130. Instead of standardized metadata, each of these repositories used its own questionnaires to collect information used to classify its items, and later query them. In the case of ClarkChart, the questionnaire includes ∼40 fields, with only the game's name and download URL are marked as mandatory. The Serious Game Directory, curated by the Serious Game Association (a consortium with both researchers and private-sector companies) has a ∼30-field questionnaire, all of them required when adding an entry.

C. Challenges of LO Reuse

The problem of LO reuse is similar to that found in many emergent technologies: content authors (supply) may not see a compelling benefit or enough demand to justify the investment of large quantities of time and effort to package and describe (via metadata) their content as high-quality LOs. At the same time, educators that could be interested in such contents (demand) may balk at a perceived insufficient supply, since current LO repositories make it difficult to find quality LOs for complex educational needs without investing significant search effort – assuming that such an LO is actually present in the first place.

In general, a larger supply of quality LOs would result in increased demand (as the likelihood of successful searches would increase), assuming that the search and evaluation process works as it should. On the other hand, a larger demand would stimulate authoring, since LO authors generally strive for the maximum impact for their authoring efforts.

Other reuse-enhancing mechanisms do exist, beyond the above-mentioned positive feedback cycle. Demand can be stimulated by minimizing the costs associated with finding suitable LOs for a given educational context; and supply can be likewise increased by minimizing authoring, metadata, packaging and sharing costs. In this sense, by tapping alternate metadata sources, LO reuse can be significantly bolstered. In [14], Duval and Hodgins identified multiple such sources (more details are available at [15]).

These sources can be categorized as follows:

- Context of use: due to the use of Virtual Learning Environments to host and deliver LOs, use-context (or even reuse-context) for LOs can be used to infer its specific field of knowledge, degree of depth and target student population. Surrounding LOs can also provide similar clues. Fig. 2 contains a proposal which exploits this metadata source in an automated fashion to streamline both LO sharing and later location for reuse.
- Context of creation: most authors specialize in the creation of LOs for a narrow set of disciplines and educational levels. Given one or more LOs by a given author, it is possible to make highly accurate guesses regarding the metadata for additional LOs from the same author [16].
- Reviews: many repositories allow their users to write reviews for LOs that they have used or have been asked to review. These metadata are one of the few ways of evaluating actual LO quality; and the endorsement that they imply for LO authors can provide a strong stimulus for further LO authoring and continued improvement of existing, well-received LOs. The existence of an active community dedicated to authoring, reviewing and reusing LOs from a repository is, according to [17], an important indicator of repository health.
- Internal analysis: automated analysis of LO contents can be an important metadata source. Although text analysis for, say, keyword extraction is easy to perform and well understood, automated extraction is significantly more complex in the presence of multimedia and interactive contents, such as games and simulations.
- Usage experience: finally, the degree of success of LO users can be collected and analyzed. This requires the use of some kind of Learning Analytics infrastructure to collect the data and extract meaningful results. However, it can provide important information which is orthogonal to all other sources on actual LO success.

The proposal illustrated in Fig. 2 would simplify LO sharing within an LMS such as Moodle: to share an LO currently in use within a course, context-of-use metadata would be automatically extracted from the table-of-contents of the course that it is embedded in. The same mechanism could be used to query the repository for "LOs with a similar context of use to a given course", essentially allowing a single-click search for compatible LOs. This proposal arose during the first meeting, in June 2013, of the Iberoamerican Network for Educational Repository Usability (Red Iberoamericana para la Usabilidad de Repositorios Educativos: RIURE) [18]. The first part

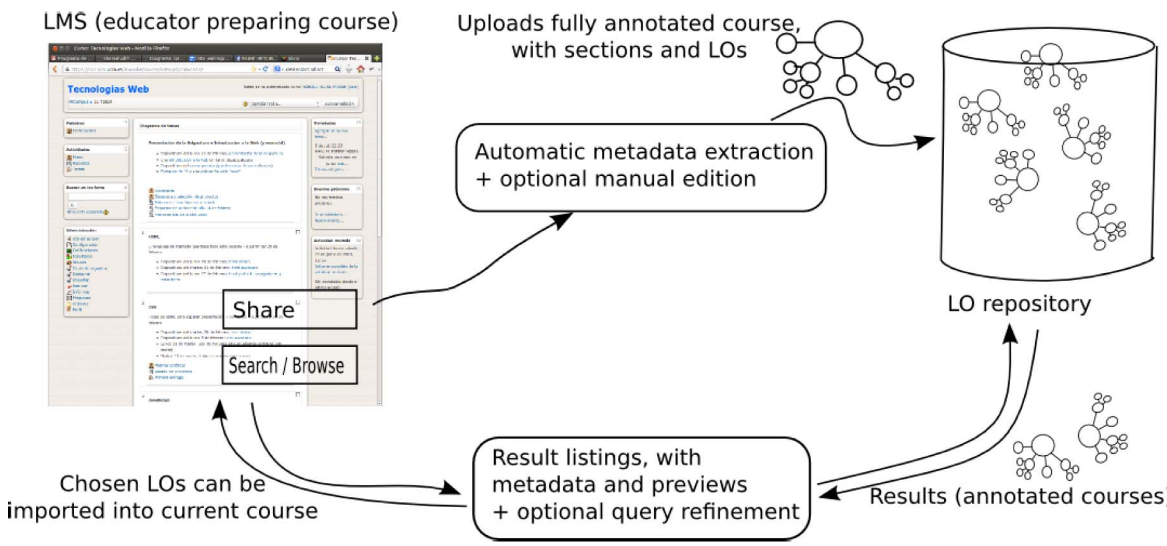

Fig. 2. A proposal to streamline and simplify LO reuse using metadata derived from use context: the position of a given LO within an LMS, such as Moodle, allows a great deal of metadata to be inferred, including educational context and level of difficulty. The same mechanism can be used to formulate queries that would return LOs with similar use-context.

of Fig. 2's proposal would allow automatic packaging as LO of any content used in an LMS; and could be deployed institution-wide, in a similar fashion to the system described in [15]. These same LOs could be enriched, later on, with usage and performance data extracted from a Learning Analytics platform that monitored student interactions with the LMS (and ideally, related academic outcomes in non-LMS mediated exams). In all cases, automatically extracted metadata would be visible for content authors or educators using them to pre-populate queries. As long as the extracted metadata presents few errors that need correction, the goal of lowering demand and supply barriers will have been met.

For educators that wish to find suitable LOs for a given course, good metadata allows queries to retrieve only the most relevant results. However, once any set of results has been returned for a given query, the educator must still evaluate these results to see which, if any, satisfy the educational need. This triage phase is critical (let us imagine that hundreds of results have been returned for a given query). Given dependable data on quality and educational effectiveness, these can be used to rank results, so that only the most relevant will need to be evaluated. In web search engines, this approach is complemented with small automatically-generated abstracts for each result. In the LOs returned by queries to the repositories of Table I, these abstracts are part of the metadata submitted with the LO. While we are certainly not the first to suggest automation of this type of metadata (as the references in this chapter bear witness), we consider automatically-generated metadata to be a critical part of any serious game metadata proposal.

III. Improving Game Metadata

This section focuses on the specific challenges presented by the use of serious games as LOs, and more specifically those of generating suitable game-specific metadata. As mentioned in Section II, games are different from other types of LOs in their use of interaction mechanics that, together with an associated narrative, provide a high degree of immersion. Typically, game mechanics and narratives allow players to experience different paths through the overall story, providing a degree of replayability. Finally, high interactivity (especially when compared with other LOs) makes games an impressive source of Learning Analytics data.

From the point of view of metadata sources such as context-of-use, reviews or creation-context, games are not significantly different from other types of LOs. However, two sources of partially-automatable metadata do warrant separate analysis: internal game analysis and usage experience.

A. Metadata Assisted by Internal Game Analysis

Any interaction with a graphical device can be captured in video. In a game where actions and their results are immediately visible on the screen, a gameplay session can be reconstructed, with very high fidelity, through the resulting video. Bearing in mind the great importance of graphics in games and their highly-customized user interfaces, these "gameplay videos" are frequently used in the game industry to demonstrate game characteristics for evaluation and tutorial purposes. For instance, in the ClarkChart [12] game-specific repository, many games include such videos. Through a suitably-chosen video sequence, game mechanics, narrative quality, educational approach and other characteristics can be accurately showcased. Several video sequences can be chosen to provide insight into multiple characteristics at once. Although videos are not appropriate for repository queries, they are very valuable for evaluating results of queries performed using any other metadata as search terms.

In LOs with a lower degree of interactivity, such videos are neither necessary nor useful. For instance, for static documents, self-evaluated exercises, or images, educators can assess suitability in just a few quick glances with minimal investment.

From the game-authoring environment, it should be generally possible to automate video generation. However, authors must be involved to choose sequences and gameplays deemed to be representative of one or more gameplay characteristics. It is also possible to generate gameplay sequences from outside the authoring environment; however, this requires significant familiarity with video and audio capture and editing tools on the part of whoever is creating the video. This is why the e-UCM group is integrating gameplay-video generation into newer version of the e-UCM serious game authoring environment: gameplay videos will be automatically generated by the tool based on one or more sequences marked by authors as "representative".

Asides from gameplay videos, there are many other types of metadata that can be useful to classify games. Most notably, classifications based on interaction types or visual metaphors can be of great assistance. In addition to such characteristics being useful to query for games (as in "games that allow direct control of a 2D avatar" vs. "games based on dialogue interaction"), the existence of other mechanics such as temporal pressure or a high degree of manual dexterity may also have a significant impact in game accessibility [19]. Unfortunately, there is no wide consensus either on standardized game-description vocabularies or game-classification taxonomies in general [20]. As an example of the existing diversity of game mechanics, BoardGameGeek (a popular website dedicated to board games) lists over 50 game mechanics [21] to be found in the over 74000 games that it indexes. Even without strong consensus, a first step is to expose, as part of LO packaging, as many details as possible on these internal mechanics. With few exceptions, there is no one-to-one mapping between game elements and mechanics – this precludes authoring environments from being able to automatically generating "game mechanics" metadata. However, for the few cases where this is possible, it is highly desirable – anything that reduces authoring burden will result in more metadata.

B. Metadata Derived From Usage Experience

Games generate large quantities of interaction information, as they contain very short feedback cycles with constant user input. This collected information allows usage metadata to be generated, assuming that it is indeed collected and aggregated. The aggregation mechanism should be specified, configured and enabled as a part of the packaging phase. For example, the GLEANER [22] Game Learning Analytics system has been used for precisely this task in e-Adventure games, and could be easily extended to generate aggregate data on average user gameplay time, success rate and other metrics which would then be periodically added into the corresponding game-LO metadata.

C. Experimental Validation Proposal

This subsection describes experiments that would allow the main proposals contained in the present work to be experimentally validated and verified. In the first place, we would require a serious game to be developed with support for the 3 main types of game-specific metadata: *gameplay videos* showcasing characteristics, *duration-and-effectiveness* learning-analytics results, and *game-mechanics* classifications (say, using an abridged of BoardGameGeek's classification). We propose the use of the Mokap Platform [23], which is open-sourced and developed by the author's group.

We consider the following research questions:

1. From the point of view of metadata creation, what is the cost, in execution time and required training, of adding metadata from each of the 3 sources?
2. From the point of view of an educator evaluating resources, how useful is each source?

To answer the first research question on authoring costs, we propose a first experiment where a set of volunteer participants is given a simple game under construction with a suitable authoring environment, and instructions on how to add each of the 3 types of metadata, provided by an instructor. In an initial phase, participants would be guided step-by-step by the instructor. In a second, experimental phase, participants would be requested to repeat the same steps for a different game. Difficulty would be measured based on task-times and completion rates, and also by a (subjective) post-task questionnaire. We believe that, for a simple game authored with a tool that supports gameplay video generation, *gameplay videos* could be generated in a fraction of the time required to actually finish the game; *game-mechanic* classifications could be quickly filled by checking applicable mechanics from a menu with descriptions, and given easy-to-activate tracking and a running LA system such as GLEANER, *duration-and-difficulty* data would not require much more than a few play-throughs to be generated.

To answer the second research question, on the effectiveness of each metadata type from the point of view of evaluation, we propose the development of metadata of each type for a small collection of games (<30). We would develop a web-based faceted-search interface, inspired on that found in current LO repositories, where ~5 results at most would be shown without scrolling; and the possibility of refining queries and sorting results on any sortable criteria. The experiment would consist in requesting participants to find the 3 closest matches to a set of 4 pre-defined "educational needs" chosen by the researchers. The first of the 4 test-cases would be discarded as training, but for each of the 3 remaining cases, elapsed time and degree of accuracy would be compared, and participants would be requested to fill in an additional post-task questionnaire to assess subjective remarks regarding the experiment. We would expect to find that the 3 types of metadata are complementary, and that their usefulness depends in great degree on the details supplied as part of the educational need supplied by the resources for each use-case. For example, while filtering for "estimated duration" is a straightforward, evaluating whether a game contains "graphical violence" would require, in the absence of additional metadata, playing through the full game – or concluding from the provided gameplay videos that such violence was either present or very unlikely.

IV. Conclusions and Future Work

In spite of the growing adoption of Virtual Learning Environments (VLEs) by educational institutions worldwide, LO reuse is still relatively rare.

With the goal of reducing the barriers that keep LO reuse levels low in the specific case of game LOs, we advocate for partial automation of metadata generation, both through exploiting their placement within VLEs and via specific support from the authoring tools with which such games are created in the first place.

For serious games used as LOs, we describe strategies both to facilitate their evaluation by humans (gameplay videos) and to improve their indexing and later search & retrieval from repositories, using metadata that provide details on their narrative, replayability, game mechanics, and typical difficulty and duration. These 3 strategies are complementary, and would all benefit from specific support from serious game authoring tools. We also propose two experiments to validate our hypothesis.

As future work, we intend to finish integrating these automation techniques into an actual authoring tool, and carry on the suggested experimental validations.

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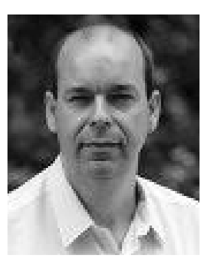

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