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TEACHING MATERIALS REPOSITORY*

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Abstract. The paper presents results from the development of a methodology and corresponding software tools for building an academic repository. The repository was filled up with gaming material. The repository architecture and key features of the search engine are discussed. The emphasis falls on solutions of the large set of problems concerning the development of proper mechanisms for semantics-based search in a digital repository.

1. Introduction. The booming game industry and the rising interest of students in game technology has led to the introduction of game courses and degree programs in computer science departments worldwide. The vastness of topics in game technology, the rapid speed of innovations in the industry, and the lack of easily accessible instructional modules has blocked the wide dissemination of teaching materials and innovations in the gaming educational community. Furthermore, these technological and pedagogical hurdles hinder the incorporation of

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gaming examples into introductory courses, which would lead to increased retention of computer science students—students who might be interested in gaming, but fail to see the connection of foundational course material and gaming.

Initiatives for the deployment of e-infrastructures are well underway across the globe. Long-term national and international deployment efforts for network, computational, and data grids can be found in Europe (GÉANT, EGEE, DEISA, NGS, D-Grid, NDGF) [1], the United States (TeraGrid, OSG), China (CROWN), Japan (NAREGI), India (Garuda), Australia (APAC), and the countries of the Pacific Rim (PRAGMA) [2]. Focusing on higher levels of abstraction, infrastructural support shows a greater variety of forms, both in the context of individual disciplines (domain-specific services) and, more horizontally, within the scope of specific functionalities (cross-domain services). Infrastructure solutions generally differ from the resource model they adopt, that is, the categories of resources they handle (e.g., hardware, software, content, running software), and the specific application domain they target—for example, the EFG project operates over movie information resources, the CLARIN project focuses on natural language resources, DILIGENT and D4Science target the European Space Agency and FAO fishery data resources, while BRICKS integrates digital cultural resources.

The paper describes an online, open repository. The repository was filled up with teaching modules in gaming topics that foster teaching innovations and interaction between educators. This repository serves as a hub for hosting teaching modules developed by educators, and it serves as a platform for evaluation, feedback, and improving available teaching modules. The design is based on the European Digital Library Project funded by the European Commission under the eContentplus Programme and coordinated by the German National Library, which is a leading example of a digital library. Furthermore, the modules that are available in this repository can be used to support community outreach activities such as workshops, camps and campus visits that stimulate wider awareness of computing and opportunities within the gaming framework.

Important results from the development of a methodology and the corresponding software tools for building an academic repository with gaming materials are discussed in the paper. The paper is organized in the following way. Section 2 presents the developed repository: the main features, the system architecture, and the key features of the Game Teaching Materials Repository (GTMR) Search Engine. Examples of using GTMR are described in Section 3. In Section 4, tools for entering teaching materials in GTMR are discussed. Section 5 shows our approach to evaluating the GTMR framework. The paper ends with a conclusion and plans for future work.

2. Game teaching materials repository (GTMR). The developed GTMR is based on the **Open Archives Initiative (OAI—see** `http://www.openarchives.org/`). The initiative develops and promotes interoperability standards that aim to facilitate the efficient dissemination of content. OAI has its roots in the open access and institutional repository movements. Continued support of this work remains a cornerstone of the Open Archives program. Over time, however, the work of OAI has expanded to promote broad access to digital resources for eScholarship, eLearning, and eScience. The proposed schema for OAP is given in Figure 1.

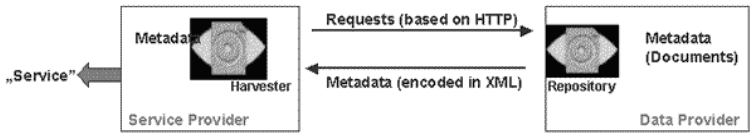

Fig. 1. Open Archives Initiative (OAI) service

In the development phase, the following systems were analyzed and some of their solutions were used in our design.

- **Open Educational Resources (OER)** (`http://www.oercommons.org/`). In a brave new world of learning, OER content is made free to use or share, and in some cases, to change and share again, made possible through licensing, so that both teachers and learners can share what they know. Another open trend that is growing quickly is the adoption of open source textbooks. OER focuses not only on textbooks, but also on full courses, course materials, modules, journals, streaming videos, tests, software, and any other tools, materials, or techniques that are critical in the learning environment.
- Moodle (`http://moodle.org`)—a course management system (CMS)—a free, open source software package designed upon pedagogical principles, to help educators create effective online learning communities. Moodle's features include: classes, individual logins, student activity tracking, grading, moderated blogs and forums, calendars, file upload and download, surveys, quizzes, assignments, wikis, and email alerts.
- DSpace—one of the most used Digital Repository Systems (`http://www.dspace.org/`)—an open source software platform for creating digital library that enables institutions to:
  - Collect and organize their intellectual production, collection, describing and disseminating digital works, digital objects, performing full-text retrieval through different search options and network points;

  - Distribute their digital works over the web through a search and retrieval system; and
  - Preserve digital works over the long term.
- MediaWiki [13], publicly available wiki software.
- A Semantic Web Powered Distributed Digital Library System [3, 4]. The Semantic Web is an extension of the current Web in which information can be expressed in a machine understandable format and can be processed automatically by software agents. The semantic web enables data interoperability, allowing data to be shared and reused across heterogeneous applications and communities.

2.1 GTMR: main features. The digital repository GTMR is designed for materials that support research and education at an institution [12] and are primarily implemented and managed by the libraries of the same institution. Open access repositories have a few very important features, namely the allocation of standard persistent identifiers to uploaded full-texts/objects (i.e., URN, DOI or similar), the capability to download statistics, and the usage rights information (i.e., machine readable data such as Creative Commons licenses). The repository encourages open access business models among faculty and publishers by giving centralized access and visibility to game teaching materials.

The main GTMR features include:

Game teaching materials storage: functionalities for storing an Information Space of teaching materials. The materials in the repository contain the following elements.

- The audience: Game development is a highly creative and interdisciplinary process. Students interested in game development can come from diverse backgrounds. It is naturally a different thing to teach a group of students that are computer science major and to teach students whose majors are in arts, literature, or humanity. Teaching materials should give a detailed description on the intended student body to facilitate the adoption by other educators.
- Listing of prerequisite knowledge materials: Identifying and listing the prior knowledge required for learning the material. These must be clearly stated and there should be a link to where such knowledge material can be found.
- Hardware/Software requirements: There is a large number of software and hardware platforms for development. It is important for educators to describe clearly the software packages and hardware platform they use so that other educators can quickly determine whether the material is applicable

based on the existing resources at their institutions.

- The content of the material: Listing the topics. We are using a classification schema for the game ontology proposed by the International Game Developers Association—IGDA (`http://www.igda.org/`).
- The instructional methodology: Teaching materials should contain a description of the teaching methodology. The teaching methodology addresses the way the class is taught. There are several formats for teaching a game technology class, including on-line instruction, video streaming, face-to-face, various distance learning methods.
- Instructional material: It contains the learning objectives and leads to easy assessment.
- Presentation of just-in-time activities: In any student-centered and learner-centered material, there must be just-in-time hands-on activities that include modifying a piece of code for an alternate or added functionality. These activities make the material more usable and exchangeable.
- Presentation of multimedia: Types of supporting standards for presenting graphics, video and audio within the repository.
- Evaluation of learning: Some teaching materials can contain sample reading and hands-on lab assignments and evaluation techniques to ensure that the learning objectives are met.
- Linking to related resources: For some materials, links to related resources have to be provided.

Game teaching materials deposition: includes functionalities and web interfaces for supporting authors. The area includes automatic deposition functionalities that can guarantee that vocabularies (that is, institutions, countries, languages) to be used in material descriptions are correctly maintained.

Game teaching materials presentation and retrieval: includes an end-user portal to search and browse the Information Space and to inspect the statistics on content and access.

2.2 GTMR Architecture. GTMR is based on the Open Archives Initiative (OAI) which allows: (a) world-wide consolidation of scholarly archives; (b) free access to the archives (at least metadata) via consistent interfaces for archives and service providers; (c) low barrier protocol/effortless implementation.

GTMR holds three types of metadata about archived content: (a) Descriptive Metadata—each item has one qualified Dublin Core metadata record; (b) Administrative Metadata—this includes preservation metadata, provenance and authorization policy data; and (c) Structural Metadata. This includes information about how to present an item, or the bit streams within an item, to an

end user and the relationships between the constituent parts of the item. The functional model of the repository is shown in Figure 2.

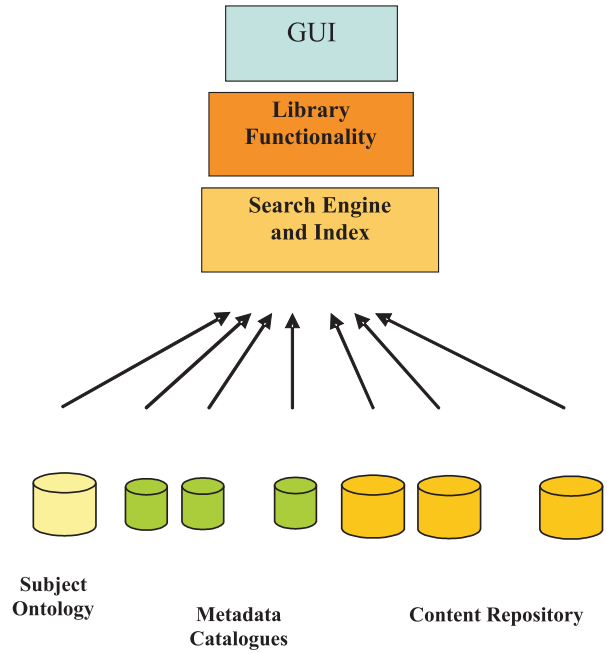

Fig. 2. The GTMR functional model

The content repository includes teaching materials in various digital formats such as: pdf, html, plain text, doc, ppt, jpeg, video, etc. Currently the repository contains some materials recommended by IGDA (`http://www.igda.org/`). The metadata catalogues are designed so that they can facilitate the identification of learning materials by the search engine. The catalogues contain descriptive metadata (stored in XML format) that comply with the IEEE Standard for Learning Object Metadata [5]. As a result, the metadata catalogues support the reusability of learning materials, aid discoverability, and facilitate their interoperability. Typical examples of the relevant attributes of educational materials are: type of the material, author, title of the material; language(s) (human and/or programming), digital format, location, version, date of creation, completion status, restrictions on use, and semantic annotation—a list of concepts from the subject ontology describing the gaming subfields and/or concepts covered or treated by the material. Each catalogue entry (i.e., each

resource description) consists of two equivalent parts in which the element values are currently in Bulgarian or English. The search engine examines the parts of the descriptions according to the language of the user query.

The subject ontology is based on the game curriculum proposed by IGDA (`http://www.igda.org/`). It was developed using the graphical user interface of Protégé/OWL and the DIG code generated automatically within the framework of Protégé. The search engine provides access to the complete palette of information stored in the repository. The current version is implemented as a Web application in PHP 5 and uses the Apache Web server.

2.3. Key Features of the GTMR Search Engine. The design principles of the search engine are based on the use of well-known methodologies for Semantic Web applications. In building the prototype we followed principles used by the repository for cultural heritage [6] and several popular specialized academic digital libraries [7–9]. We provided personalized digital library access with preference-based queries [10] and used advanced search engine technologies that are successfully applied in digital libraries [11]. The GTMR search engine is responsible for locating the user-desired resources stored in the content repository. It accepts metadata queries that are based on the properties of resources and returns a list of metadata descriptions and references pointing to the corresponding repository individuals. The search engine uses as auxiliary structures an index of the metadata catalogues and a dictionary of synonyms of the subject ontology concepts.

The search engine supports several types of searches. The user queries define restrictions on the values of certain metadata attributes of the required learning materials. The search mechanism performs consecutive examination of documents' descriptions. In the current implementation, the following kinds of document search and retrieval are supported:

- search/extraction of all available documents of the collection (full search), ordered by: Title, Author, Category, Date written or by Date added in the library;
- search for the documents that are created by given author (author search)—the search uses the value of element <authors>;
- ontological search—the search uses the value of element <ontologyRefs>;
- keywords search—the search uses the value of element <keywords>.

The elements <ontologyRefs> and <keywords> are part of the catalogue descriptions. They serve as a semantic annotation of the corresponding documents. The value of the element <ontologyRefs> is the list of concepts of the subject ontology (class names of the subject ontology) that correspond to the

content of the described document. During a search in the ontology, the user's request is expanded with more specific concepts (successors) from the descriptive ontology. The search engine extracts all documents in which the <ontologyRefs> element has been encountered. The concepts of the subject ontology are too general from the point of view of the expectations of the typical users of the GTMR. For this reason one can include in the catalogue descriptions additional lists of keywords which describe the content of the corresponding documents at the required level of abstraction. These keywords are set as values of the child elements of the <keywords> resource description elements.

3. Example of GTMR use. The current version of GTMR can be found on `http://webtech.kettering.edu/~pstanche/GamingDL/`. Suppose the user specifies a request for ontological search about the concept "game production". Then an extension of this request with all relevant ontological concepts will be made first. The ontology graph will be traversed, starting from the concept chosen by the user. In our case, using the game ontology proposed by IGDA (`http://www.igda.org/`), an extended request is received. It includes the concepts "game production", "architecture", "architecture testing", "communication skills", "coordinating the efforts of development", "defect tracking", "design and development documentation", ..., "working with marketing", "fundamental principles of architecture", "history of architecture",..., "test plan" (see Figure 3 or visit `http://webtech.kettering.edu/~pstanche/GamingDL/`).

After that, a consecutive search in the catalogue descriptions is conducted. In this search all documents whose descriptions are juxtaposed with at least one element of the extended request are extracted. Figure 4 shows some results that are received by ontology search with a request "game production".

4. Entering teaching materials in GTMR. The teaching knowledge base includes both precollege and undergraduate materials. We used materials proposed from IGDA (`http://www.igda.org/`) as initial texts to enter in the repository. In the future, teaching materials will be deposited though the following steps.

a) Open the repository to the students and faculty at Sofia University and Kettering University. The materials will cover a wide range of topics such as mesh editing, animation, armature, game engine, sound editing, the elements of game design, interactive fiction, storytelling, game playing, the genres of games, geometry and matrices, transformations and motions, game physics, languages and operating systems and game tools. We will

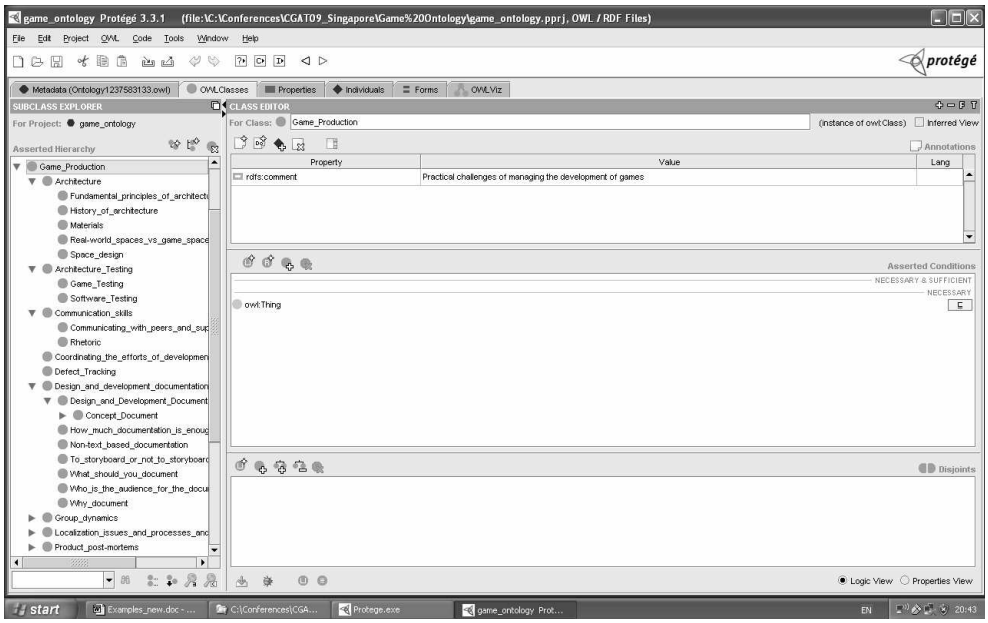

Fig. 3. Part of the concept hierarchy

Fig. 4. Ontology search results for the query “game production”

also put sample labs and example student work into the repository. Undergraduate students will be used at this step too.

b) Open the access of the repository to Wayne State University, National Heritage Academia Schools, the Genesee Intermediate School District (GISD), Simon Fraser University, and Wayne State University. Over the years, these universities have developed high-quality materials for game education. National Heritage Academic Schools provides excellent education for children from kindergarten to grade eight. Their involvement is critical to our vision of reaching out to the community and especially nurturing the next generation of computer science professionals. By opening the repository to GISD, K-12 educators and students will be able to use the repository and contribute to it and we can get suggestions and advice on how the repository can be improved before its world-wide release.

c) Open the access world-wide. At this stage, the repository and the teaching materials in it will have been tested and reviewed by the investigators and our regional and international partners. By allowing world-wide access, we will make the repository and the educational modules freely available. It is our commitment to maintain an active community for the review, development, and dissemination of the repository. We believe that, through the involvement of educators and students around the world, not only the repository will grow, but also we will build a foundation for change in the education model of K-12 and higher education.

5. GTMR Evaluation. We will evaluate the success of the repository from two perspectives. The first is the design of the repository and the second is the quality of the educational materials. Details follow.

a) Evaluation of repository creation.
We plan to evaluate the repository in three ways. One way is through outside consultants, who are going to analyze the overall design of the repository. The second is through the feedback of educators. The third is through the feedback of students. After any major development of the repository, we will invite our partners to have a look and give us advice in the area of design strategy, usability, and interface. We will also provide a convenient form for the viewers of the repository to give general suggestion and feedback. Another way of evaluation is the comparison of our repository with the educational repositories for other disciplines such as Applied Math and Science Education Repository—`http://amser.org/`, Formal Methods Education Resources—`http://www.cs.indiana.edu/formal-methods-education/`,

Learning Science and Technology Repository— `http://lester.rice.edu/DesktopDefault.aspx`.

b) Evaluating the repository use.
Based on [14] we will go through the following steps:
   1. Evaluating the presentation aesthetics: selection of fonts and colors, writing style, legibility of text, and other production values.
   2. Evaluating the presentation design for learning: formatting, highlighting and sequencing of information.
   3. Evaluating the accuracy of content: veracity, accuracy, level of detail, and educational significance of the knowledge.
   4. Evaluating the support for learning goals: the alignment of learning activities, content and assessment to the goals.
   5. Evaluating the student motivation: the ability to motivate, and stimulate the interest of, an identified population of learners.
   6. Evaluating the interaction usability: ease of navigation, predictability of the user interface, and the quality of UI help features.
   7. Evaluating the interaction feedback and adaption: adaptive content driven by differential learner input or learner modeling.
   8. Evaluating the reusability: ability to port between different courses or learning contexts without modification.
   9. Evaluating the accessibility: support for learners from diverse backgrounds and with varying capability.

c) Evaluation of the education materials.
We are going to evaluate the educational materials through the user feedback and the number of downloads. For each material, a registered user will be able to rate it in several categories and give brief feedback. For the materials that are put there by the investigators, explicit invitation will be sent to our partners for evaluation. We will ask our partners to try using the materials in their classes and provide feedback.

We will measure faculty and students' satisfaction and interest from the project in the following ways.

a) Evaluation forms have long been used in our pre-college programs to determine overall satisfaction by these programs. Additional questions will be added to address these new teaching materials and their usage.

b) Long-term tracking of our pre-college programs is already happening. We will include questions pertaining to these new materials to get a longer term

impact of these new initiatives on students' eventual college choices.

c) Evaluation data exists for previously taught courses. We will examine new evaluation material to determine the measure of satisfaction. (Recognizing that satisfaction results from many different factors.)

d) JETT Program: JETT—The Java Engagement for Teacher Training Program (JETT) is a partnership between ACM's Computer Science Teachers Association and the College Board. JETT provides quality pedagogically-oriented workshops and resources in Java for secondary high school computer science teachers. Kettering University Computer Science has provided several JETT workshops, and this will provide us with a mechanism to present the repository to high-school teachers for evaluation. In addition, we have maintained contact with past participants, and we will use this group of educators as focus groups.

e) We will use the participants in a game workshop for evaluation of the repository.

6. Summary and Future Work. The lack of a unified and easily accessible repository for the exchange of teaching materials has adversely affected the wide adoption of innovative, learner-centered instructional techniques in gaming courses. Since there is no general consensus on topics to be covered in a gaming course, nor even a consensus on what technical courses need to be included in a gaming degree/concentration, it has been difficult for educators to share course materials. The repository provides a convenient interface for educators and students to upload/download teaching materials and provide assessment. The online repository helps greatly the exchange and dissemination of teaching materials and innovations of undergraduate computer science students. The repository has the potential to become an online hub for hosting teaching modules from practitioners in game technology and innovative computer science teachers. The developed repository can be filled up with materials from other subjects.

The repository bridges not only the gap between curriculum and actual teaching but also the gap between educators for exchanging teaching innovations. The enhanced exchange of teaching innovations will improve the overall quality of teaching in computer science and foster the learning experience of students, thus improving the enrollment, retention, and graduation rates.

A dictionary of synonyms has been under development with the purpose of providing the search engine with other viewpoints to the conceptual structure of the area of gaming. The idea here is to provide a possibility for two-stage execution of the user query. During the first stage, the request will be extended

with more specific concepts (its successors) from the subject ontology. At the second stage, the synonyms found in the dictionary will be added to the main concept, which is specified by the user, and its successors.

In this paper we presented a methodology for building an academic digital repository using Semantic Web technologies and publicly available software. Compared to some well-known large-scale initiatives, such as the ones that were discussed in Section 2, our outcome is of a smaller scale, but in contrast to all of them, it investigates the use of an ontology, which makes it possible to provide more flexible, semantics-oriented access to resources for users with different profiles. The application of free-license software, which can be used by developers of institutional digital libraries, is an additional advantage of the suggested approach.

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