Recent development in multimedia e-learning technologies

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Abstract Multimedia and networking technologies have significantly impacted on our daily activities, particularly in terms of how we learn. Nowadays, classroom teaching no longer simply relies on chalk and blackboard as the prime medium for course dissemination. E-learning technologies have made it possible to provide a virtual classroom environment on the Web through supporting teacher-student and student-student communications, course material distribution as well as online student assessments. They provide students with more control over their learning schedule and pace. On top of this, multimedia technologies further offer students different forms of media to match their learning styles, leading to enhancements of their learning effectiveness. This extended introduction discusses the latest e-learning specific multimedia technologies, their research challenges and future trends from both pedagogical and technological perspectives. We also summarize the papers included in this special issue.

Keywords Multimedia e-learning technologies · Communication e-learning technologies · E-learning research

1 Introduction

From the content presentation perspective in learning, multimedia and networking technologies have helped transform traditional media, such as books, tables, figures and blackboard writing, into online and interactive forms. These new forms of learning materials can be accessed by students from anywhere and at anytime through the Internet. In addition, multimedia technologies may facilitate the presentation of learning materials adaptively and in different forms. Pedagogically, such enrichments are essential for delivering personalized learning materials to students with different learning styles [8]. These enrichments allow students to learn more effectively when the learning materials are presented in suitable forms, such as video, audio or text. From the system perspective, e-learning refers to an Internet-based learning platform, where students and teachers may interact or collaborate with each other [16]. For example, teachers can raise topics for online discussion that allow remote students to work together on these topics. In terms of student assessment, e-learning systems allow students to submit their coursework and receive individual feedbacks online.

Improving student learning effectiveness and experience are long-standing objectives in the development of learning technologies. Many projects have been conducted in the domain of multimedia technologies to help fulfill these objectives. They particularly contribute to several areas: individual learning experiences, collaborative learning, learning paradigm and learning content. For example, location-aware devices and applications have been developed to help support situational learning, which enhances student understanding and learning experience. Collaborative networking technologies are being developed to connect remote students together to form groups and to allow them to work together in a shared environment. On the other hand, new forms of learning paradigm, such as game-based learning, have been proposed both to motivate students to learn and to enhance student learning effectiveness and experience. Finally, a lot of media types have been developed and are being used for delivering learning materials. While the selection of suitable media types may be important to learning effectiveness, intuitive authoring tools are also desirable in easing the production of such media.

2 Emerging multimedia technologies for e-learning

Multimedia technologies broadly refer to the development and the use of various types of media and communication technologies to enhance content visualization and user interaction. Multimedia technology integration is becoming a core part in the development of e-learning technologies. In this section, we introduce the emerging multimedia technologies that contribute to the development of e-learning technologies. We broadly categorize such technologies based on media that induce substantial changes to the student learning process, and content that improves student learning effectiveness and experience.

2.1 Media changing the learning process

The main objective of media is to provide channels for the delivery of various forms of contents. With the availability of new media types in recent years, substantial changes have been made to the student learning process. There are three important types of media.

2.1.1 Communication technologies as a medium for e-learning

The development of communication technologies, such as mobile devices and RFID (radio frequency identification), is fundamental to providing more convenient ways for instructors and learners to interact and collaborate with each other. It facilitates the delivery of learning materials and improves the accessibility of e-learning applications.

This type of media is important to the construction of seamlessly integrated learning environments that feature permanency, accessibility, immediacy, interactivity, and situated learning. The hybridization of communication devices further enriches learning environments. For example, the UPS (Ubiquitous Personal Study) [3] integrates the concept of ubiquitous computing by using mobile phones for improving the accessibility of learning content and applying Web 2.0 to provide personalized learning environments. Another example is supporting language learning through a ubiquitous environment. TANGO (Tag Added learNinG Objects) [23] detects objects around a learner through RFID tags and provides the student with relevant context information. The system examines a student's understanding by real-time questions. If the student can correctly answer the questions, he/she can receive further information about the corresponding objects. These examples show that the use of ubiquitous devices may motivate and improve learning in terms of curiosity, interactivity and engagement.

2.1.2 Social networks as a medium for e-learning

Social technologies (or social media) refer to the use of communication channels, such as the Internet or mobile networks, for establishing and maintaining user groups/communities, where information sharing and social interaction are supported. In social interaction, users may be grouped under various forms of communities based on events or situations [1].

With the growth of social technologies, social learning is beginning to emerge. It offers powerful and enduring learning experiences through the use of social networks, such as online communities, where learners are engaged to discuss, formulate and share knowledge/information. An empirical study in [27] shows that users have higher motivation to learn new things/knowledge when exposed in a highly-interactive environment. Rienties, et al. present a series of empirical studies on a large number of college and graduate students [26]. Results show that student collaboration surpasses individual learning and improves student motivation and learning performance. These studies also identify the feasibility of using user-generated information in socialized environments. Evidences reveal that the use of social media indeed strengthens the relationships that learners have established offline and provides learners with the sense of participation [18]. Hence, social technologies help establish and manage connections that facilitate social learning.

2.1.3 Games as a medium for e-learning

Game-based learning (GBL) research is becoming popular recently, as researchers find that the paradigm can significantly motivate students to learn. GBL is supported by a set of technologies, including multimedia communication, computer graphics, human-computer interaction, and ubiquitous computing. The ultimate goal of GBL is to turn the learning process into a combination of entertainment, visual-oriented and interaction-based tasks, through which students may gain a deeper understanding in their studies.

Designing the game scenario is crucial to a GBL system, as it is fundamental to how a student can quickly adapt to such a new learning paradigm and learn effectively. Along this line, virtual environment techniques have been used to develop interactive 3D environments. For instance, a script-based game environment [10] is built based on Second Life [30], which is an online platform by Linden Lab to support 3D interaction and collaboration over the Internet. It helps students learn how to solve problems based on interactions and formation of student groups. Results show that supporting student interaction and collaboration facilitate problem-solving.

On the other hand, game-based learning environments also help the formation of online communities (or specific social networks) [12]. Interestingly, games developed based on a social graph, such as Facebook, inherit similar social properties. For example, the cumulative distribution of players' (or learners') interactions follows the Power-Law decay, which can be easily predicted [11]. Instructors can make use of such prediction results to decide the types of learning content to be delivered and the types of learning processes to be included in a game.

2.2 Content for improving learning effectiveness and experience

When developing e-learning systems, we need to consider how to incorporate different forms of learning contents to improve learning effectiveness. Research in this area focuses on how to offer students the most suitable forms of learning contents and how these contents are produced.

2.2.1 Types of contents

Multimedia information [13] refers to a collective set of content in different forms, such as text, audio, images, animation and videos. Each of them requires a different data representation for storage and transmission. Content-specific compression and retrieval techniques are available. As human can concurrently process information of multiple representations, such as pictorial and verbal materials. Hence, disseminating courses by multimedia instruction may improve learning effectiveness. This has been confirmed by a recent study [17] that investigates factors that influence learning effectiveness. The study was conducted using the Blackboard system [32], a Web-based e-learning system supporting the hosting and distribution of learning content, online tests, assessment tracking and student-teacher communication. Results show that learners' self-efficacy, multimedia instruction and interactive learning activities are the dominating factors to learning effectiveness.

A main concern of using multimedia instruction is the cognitive overload problem in processing multimodal information. Mayer and Moreno propose techniques, including information segmentation, pre-training, content weeding and signaling, to address this problem [19]. These techniques provide various ways to present multimedia instruction in more manageable forms. On the other hand, interactive learning activities can be generally supported by five basic types of interactivity, namely, dialoguing, controlling, manipulating, searching and navigating [22]. These allow students to exchange questions/answers/feedbacks, control which parts of the learning content to be assessed, control the way learning contents to be presented, and identify and go through relevant learning content.

In line with the idea of applying multimedia and interactivity technologies to improve learning effectiveness, interactive videos [37] have been found to be useful in engaging and motivating students. Particularly, videos can present pre-generated learning content in motion and multimodal forms, helping students formulate and visualize abstract concepts easily. With the support of interactivity, students are allowed to proactively discover things or control the learning pace. This turns the learning process into a student-centered one.

Unlike interactive videos, which operate based on pre-generated learning contents, virtual environment (VE) based e-learning systems [6] provide graphical simulation environments with dynamic learning contents. Simulation results are produced according to user interactions. These systems may form immersive training environments for students to actively experience different situations, learn operational skills and gain hands-on experience in problem solving, rather than simply discovering and perceiving information. The immersive experience can be further enhanced by incorporating haptic technologies, such as force feedback devices and 3D input devices. As students may be accessing the servers via different types of network connection, interactive graphics rendering techniques and content streaming technologies [15] may need to be incorporated.

2.2.2 Content construction

The construction of multimedia instructions requires standards for formulating the content as well as user-friendly tools and well-defined authoring processes for authors to produce the content. Typically, multimedia instruction relies on multimodal information to represent learning contents and structural information to connect them. SCORM [31] is a popular standard for constructing hierarchical structures to connect learning contents and schedule their delivery. It also defines the communication standard for the client and server components of a web-based e-learning system. Apart from the format for content exchange, IMS Common Cartridge [33] includes standards for content authorization, student assessment and online discussion forum, providing a more complete coverage to the pedagogical needs.

Constructing multimedia instruction is not trivial, as every different type of content requires a very different method to produce, store and render. This is difficult for ordinary teachers to manage, particularly if a variety of software and development toolkits are involved. Emerging Web technologies, including HTML5, CSS3 and WebGL, try to address this issue by allowing different types of media and user interactions to be processed and rendered within a Web browser without installing a bundle of plug-ins or software. To take this further, all-in-one e-learning platforms, such as Canvas LMS [34], have been developed. This includes a rich content editor for teachers to create and edit learning content in different types of media. On the other hand, Web Services [5] allow ready-made remote e-learning services or information resources, such as Google Map, to be incorporated on-demand to enrich the dissemination of learning content.

For the authoring process, teachers traditionally assume the role of producing learning content. This means that the learning approach and pace are defined by the teachers. Recently, with the availability of Web-based collaborative editing technologies, such as wiki, the use of student-created content has been studied [35]. This exploits the fact that students can be more engaged and can learn deeply by taking the authoring role. This can be treated as a new learning approach. To ensure that students are truly benefited from this approach, the study finds that prior training should be provided to the students in order to prevent them from getting confused with the unstructured characteristic of wiki. In addition, clear apportioning of responsibilities and proper control of ownership and intellectual property should be set in place.

3 Future research directions

Based on our studies, we envision a number of research directions in developing and incorporating multimedia technologies for e-learning. We summarize four research directions as follows.

3.1 Towards the social learning paradigm

Traditional e-learning systems deliver courses based on a pre-defined curriculum and knowledge set. They assume that well-defined instructions and assessment procedures are available. Social learning (or s-learning) allows learners to receive timely information and learn from community users with similar interests. It is a powerful way for sharing opinions, stimulating discussions and facilitating learning processes. While defining social learning is still a work in progress, many researchers have been using social networking platforms to create activities and exercises for specific programs. A typical example is Elgg [28], an open source social networking platform designed specifically for online education. Social media extends learning, especially informal learning, from conventional classrooms to the global communities, offering ways to connect experts of different domains, and providing just-in-time solutions to problems. Related challenging issues include:

1. Emerging collaborative learning paradigm based on social networks—A main research issue in social learning is to improve the interactions among learners. One challenge is to identify the best-fit methods that support learning activities, such as discussions, post-and-reply and content sharing, in social environments. Such investigation may be supported by observing learners' behaviors, such as types of activities or interactions conducted.
2. Content discovery and searching—With multimedia technologies, learning content may be composed of different forms of materials. As a result, content discovery becomes non-trivial since each type of medium is different in nature. A research challenge is to develop efficient and automatic methods for discovering and delivering learning content in large-scale social environments.
3. Social behaviors mining and reuse—Student characteristics are reflected from the ways that they behave in a social environment. By capturing such behaviors, an e-learning system can better address the needs of individual students to improve learning effectiveness.

3.2 Gamification

Game-based learning (GBL) research focuses not only on applying games in education, but also on developing technologies for game designers and educational professionals to work together to produce attractive and highly-engaging GBL environments. Adequate tools should be provided for developing the system and the content. Some future research issues include:

1. Authoring and development of immersive worlds—A challenging research issue is the instructional or constructional learning design, since the role of a tutor may be turned from the traditional teaching role into a facilitator, a collaborator, a producer or an author. On the other hand, self-authored content, such as user-generated content, may lead to greater opportunity for teaching and learning in a game environment, which also matches the ultimate goal of social learning that facilitates user interactions.
2. Online gaming and its community—This research issue is related to the construction of more seamless learning experiences, which blurs the boundaries between formal institutional learning and learning at work or home. It involves the formulation and maintenance of team-based or collaborative learning. Evidences show that an online game scenario prompts learners to receive information related to specific topics of the game and provides a way for learners to use it. In addition, learning via game-playing has been proved to change and influence individuals unobtrusively and imperceptibly.

3.3 Incorporating reality as the content

Learning is a process for students to gain understanding in certain knowledge and acquire skills for dealing with certain problems or situations. Although conventional multimedia e-learning systems allow students to learning more effectively by presenting knowledge through different senses, they are not well integrated into students' physical environments. Promising research directions are envisioned to fill such a gap. They include the following.

1. Situated or context-aware learning—This develops techniques for making use of sensors to capture environmental or personal contexts, such as physical location, environmental parameters and body temperature, that form input parameters for building up a situation to support learning. In addition, wireless and mobile technologies can be integrated to support individual or group learning. It may lead to the development of learning services that can be adapted to different environments, such as hardware devices and networking conditions.
2. Mixed-reality based learning—This investigates the use of computer vision and virtual reality techniques for integrating physical objects and virtual objects/information in such a way that students may be able to explore/visualize/manipulate objects or information from both the real and the virtual worlds. Relevant research issues include developing methods to improve the accuracy and the performance of real world object recognition and designing user interaction techniques to manipulate both real and virtual objects in a seamless way.
3. Interactive student responses—Traditional student feedback, which reflects student learning experiences, is typically collected after a learning session. Interactive student responses refer to real-time feedbacks collected during a learning session. They reflect student understanding, preferences or opinions, and form part of the real-life context that can be immediately applied to adjust the learning content dissemination. In classroom teaching, interactive student responses can be collected with simple remote control devices [20]. In e-learning systems, potential research challenges of collecting interactive responses include how to incorporate multi-modal responses, which offer much richer information, and how to analyze, summarize, interpret and present the responses collected.

3.4 Effective multimedia instruction authoring

Learning activity design [7] and learning content authoring are generally time-consuming. Constructing multimedia instruction imposes additional burden and difficulty to teachers, as learning contents are in multi-modal forms, which require significantly more time and effort to produce. Despite of these overheads, constructing multimedia instruction is expected to become essential, as it can enrich knowledge dissemination. Hence, seeking effective ways to produce multimedia learning content is an important research direction. Some promising issues are as follows.

1. Development of pedagogical Web services—Web services are distributed-system technologies to allow a system to be constructed by composing dynamic software components (or Web services) provided by different organizations over the Internet. Such technologies allow the re-use of existing Web services as a way to support rapid system development and dynamic extension of system functionalities. Pedagogically, Web services can be established to re-use learning activities and multimedia instructions.

This helps shorten the development process of emerging but effort-demanding learning activities and multimedia instructions, such as game-based learning. Some e-learning platforms like Moodle [29] have already supported Web services. We believe that more pedagogical Web service components will be developed in the future.

2. Adaptive multimedia instruction authoring—Producing suitable learning content that matches student learning styles may enhance student learning effectiveness. However, the implementation is not trivial as a student may have a mixture of learning styles that change over time. This makes adaptive multimedia instruction authoring difficult. When producing multi-modal versions of learning content, teachers need to determine the learning-style-dependent relationships among learning contents, together with their delivery sequences and abstraction levels [14]. We envision that techniques will be developed for teachers to quickly preview an adaptive multimedia instruction session for a student, based on his/her learning styles. Such previews may allow teachers to review/verify their multimedia instruction design and to improve the quality of authoring processes. A good starting point along such a research direction could be employing summarization techniques [9, 21], which aim at producing abstraction of multimedia content. Main issues include the production of a unified form of abstractions to learning contents constructed by different types of media and ensuring that the abstractions produced are pedagogically meaningful.

4 Summary of papers in this special issue

This special issue collects some of the best papers presented in the tenth International Conference on Web-based Learning (ICWL 2011), which was held in Hong Kong in December 2011, and from open submissions. Among all the papers presented in ICWL 2011, we selected four best papers that are relevant to the scope of this special issue and invited the authors to submit extended versions of their papers for possible inclusion in this special issue. The extended papers were further reviewed, revised and finally accepted for publication. There are a total of five papers included in this special issue.

The first paper [25], "Providing Collaborative Learning Support with Social Media in an Integrated Environment" by Popescu (University of Craiova, Romania), proposes the use of an integrated social learning environment for collaborative learning. It presents a platform called eMUSE, which integrates learner tracking functionality, monitoring/visualization features, and grading/evaluation supports.

The second paper [2], "Teaching Modeling Skills Using a Massively Multiplayer Online Mathematics Game" by Araya, Jimenez, Bahamondez, Calfucura, Dartnell, and Soto-Andrade (Universidad de Chile, Chile), investigates how junior students learn modeling skills in Mathematics through an online massively multiplayer game.

The third paper [36], "Discovering Small-World in Association Link Networks for Association Learning" by Zhang, Luo, Xuan, Chen, and Xu (Shanghai University, China), studies the small-world properties of the ALN (Association Link Network) in providing theoretical support for association learning. It first proposes a filtering algorithm to show the small-world properties of the ALN at given network size and filter parameters. It then investigates the evolution of the small-world properties over time at different network sizes. Finally, it presents an Association Learning Model for association learning based on the small-world properties of the ALN.

The fourth paper [24], "Web-based Self- and Peer-Assessment of Teachers' Digital Competencies" by Poldoja, Valjataga, Laanpere, and Tammets (Tallinn University, Estonia), points out that there is a lack of Web-based assessment tools that allow authentic, reliable and valid assessment of the digital competencies of teachers. It addresses the design challenges related to a software solution for self- and peer-assessment of teachers' digital competencies. It then proposes a system called DigiMina for a teacher to assess herself or to be assessed by her peers using the performance indicators that are based on the competency model "NETS for Teachers" created by the International Society of Technology in Education.

The fifth paper [4], "A Hybrid Recommendation Algorithm Adapted in e-Learning Environments" by Chen, Niu, Zhao, and Li (Beijing Institute of Technology, China), studies methods to identify suitable resources for learning. It proposes a hybrid recommendation system to recommend learning items during the learning process. It is based on two approaches: discovering content-related item sets using item-based collaborative filtering, and applying the item sets to a sequential pattern mining algorithm to filter items according to common learning sequences.

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