A Systematic Review of Multimedia Resources to Support Teaching and Learning in Virtual Environments

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Abstract—The use of various types of media and communication technologies in e-learning activities enhances content visualization and user interaction, and increases learner engagement and effectiveness. The evolution of multimedia technologies in recent years has opened new opportunities of integrating multimedia resources to support on-line teaching and learning, although there is still a long way to go. In this paper, we present first an extensive state-of-the-art study of the application of multimedia resources to e-learning activities. Then, based on this study, we discuss on the benefits and drawbacks of multimedia resources and the main types of multimedia resources appropriate for e-learning purposes.

Keywords—multimedia resources; e-learning; virtual environments

I. INTRODUCTION AND MOTIVATION

Multimedia and networking technologies are found an important support for education [1][2]. These technologies have helped to transform traditional media (books, tables, figures, blackboard writing, etc.) into online and interactive learning resources, which can be accessed from anywhere and anytime through the Internet[3]. Furthermore, the development of better information and communication technologies, constantly more powerful and accessible, enables the delivery of e-learning content materials and applications, and enhances the collaboration and interactivity between students and teachers.

Multimedia technologies also make the presentation of learning materials easier to be adapted to the different learning goal. From a pedagogical perspective, this flexibility becomes essential for delivering personalized learning materials to students with different learning styles or needs [4] as well as allow students to learn more effectively and increase their motivation and engagement as some studies confirm [5].

Interactive learning activities can be generally supported by five basic types of interactions, namely [5]: dialogue, control, manipulation, search and navigation, which allow students to exchange questions or messages in general, control the parts of the learning content to be assessed, control the way learning contents are presented, and identify and go through relevant learning content. Interactive videos [7] have been found useful in engaging and motivating students, helping them to visualize abstract concepts easily. With the support of interactivity, students are allowed to proactively discover new information and control their own learning pace. This turns the learning process into a student-centered one. This view is especially relevant in the emergent educational paradigms, which consider learners as central actors in their learning process [8].

However, although many benefits have been found when applying multimedia resources to e-learning activities (see [7] or [9] as an example), they have some drawbacks or limitations that should be addressed. Therefore, abundant research work is still expected about the integration of multimedia resources into virtual educational environments. In [10], four main issues of multimedia technologies for e-learning are identified: (i) computational cost to manage complex multimedia resources; (ii) high-band network connections are required for multimedia dissemination; (iii) lack of appropriate tools on the student’s side; (iv) teaching pedagogies that make an efficient use of multimedia resources. Next paragraphs discuss on these issues in more detail.

The file sizes of multimedia resources are usually large or very large; this implies several problems, mainly due to the storage requirements, which are increased considerably, and also large multimedia resources may need a long time to be processed and require considerable computing power. Many efforts have been done in this field in order to reduce the size of these resources by using codecs and compression algorithms [11][12], although the problem is still there and must be handled when using such resources for e-learning purposes. In addition, when transmitting multimedia content through the network many communication issues may occur (problems with size limitations, lost packets, packets received in different order, security concerns, etc.). Streaming algorithms and techniques have been applied to handle and alleviate these problems, hence they have to be considered when spread of multimedia resources is needed in e-learning systems. Some examples of these algorithms and techniques can be found in [13] where a compression algorithm for streaming is presented, [14] which studies the MPEG-DASH standard for multimedia...
streaming over HTTP, [15] where a system for multimedia streaming in vehicular networks is presented, or [16] which presents a system based on a fuzzy algorithm for multimedia streaming.

Finally, the aforementioned limitations of multimedia capabilities in student’s devices are currently less problematic because of the great evolution of mobile technologies and the fact that mobile devices are widely available [17]. However, current teaching pedagogies and methodologies are still requiring being adapted to multimedia-based resources and technologies.

There are other open research issues related with multimedia resources in education, such as whilst text resources are easy to classify or index for searching, multimedia resources in the form video or audio are not. Moreover, the complexity of creating and authoring multimedia resources becomes a last issue worth mentioning here. Indeed, every type of multimedia content requires a different method to produce, store and render, thus requiring a large variety of software and development toolkits. This is particularly hard for non-technical teachers, who have to know how to use complex and little user friendly authoring tools that sometimes. This may definitely discourage them to use multimedia content for their day-to-day teaching.

In order to address the above limitations and deficiencies of multimedia resources when applied to education, emerging technologies including HTML5, CSS3 and WebGL ([18], [19]) try to address these issues 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. There are also full all-in-one e-learning platforms, such as Canvas LMS1, which includes rich content editors for teachers to create and edit learning content in different types of media.

The goal of this work is provide a throughout review and discussion on the available multimedia tools and technologies to support education in virtual environments. To this end, the next sections are organized as follows: section II describes the systematic review methodology followed in this study; section III reports the results of the review by presenting a taxonomy of multimedia resources whilst section IV explains different approaches of using these resources for e-learning. Section V discusses on the usage of multimedia resources in e-learning activities, and Section VI summarizes the main findings and sets new goals for the next iteration of the study. Finally, Section VII gives some conclusions and provide on-going and future directions of research.

II. METHODOLOGICAL STUDY

The chosen methodology for this study is an adaptation of the process for systematically reviewing literature explained in [20]. In this section we present the steps and tasks of our methodology, which are applied sequentially but may overlap in time or even repeat iteratively as needed (see Fig. 1).

A. Search and Retrieval

The process of creating a survey about the state of the art in our research field started by searching publications on an initial set of topics of interest that we defined at the beginning of the search. Published papers can be searched using some databases and search engines. To this end, we selected 150 articles from the most commonly used search portals, i.e., IEEE, ACM, Scopus, Springer, Science Direct and Web of Science. We also described the studies conducted over the past 10 years in the domain, highlighting the use of multimedia resources in education.

The terms used for the search were related to the topic being searched, starting from generic phrases to more refined and specific terminology. For instance, for the topic ‘Use of multimedia resources as learning resources’ we first searched “multimedia resources” and “learning resources”, and then we narrowed our search by combining both terms with other specific terms in this research field.

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The next step will consisted in carefully review the selected papers, identifying their structure, and distinguishing the main points. During the review of we took some notes to summarize the most important contributions commonly found in the core sections, and evaluate benefits and drawbacks of the proposed solutions.

1 http://www.instructure.com/
A. Collaborative learning

Collaborative learning tools, and Computer-Supported Collaborative Learning (CSCL) environments, enable users to collaborate in virtual environments using tools, such as forums and chats, to share questions, problems, solutions, etc. As mentioned in [40], there are some systems that extend CSCL collaboration modes to support learning activities, such as [32]-[39].

In this context, we present a taxonomy of the most known multimedia technologies currently used for education purposes. Most known [3] are described below [32]-[39] (see also Fig. 2):

1. **Social media technologies** support a new communication channel for e-learning communities. These technologies enhance students’ collaboration and motivation, which are translated into a better learning performance [32][33]. There are some proposals to mix social media with e-learning collaborative activities, such as in [34].

2. **Game-based learning (GBL)** is a recent research area that involves a set of technologies, such as multimedia communication, computer graphics, human-computer interaction, etc. The goal of GBL is to turn the learning process into a combination of entertainment, visual-oriented and interaction-based tasks, which will help students to gain deeper understanding of the subject in study [35][36].

3. **Simulations** provide graphical environments with dynamic learning content. These systems allow students to actively experience different situations, learn operational skills and gain hands-on experience in problem solving as stated by several authors like [37][38][39].

We could also find interesting information in other sections of the paper, such as the background section, where we could discover new related work (whose references we iteratively analyzed and reviewed). Also in the conclusions and further work sections we found ideas to formulate suggestions for the future research work.

The outcomes of the review phase are developed in sections III and IV.

D. Discussion and Report

The discussion step involves writing a report of the state of the art about the papers reviewed. For each paper reviewed, the main contributions were described and discussed, stating their benefits and weaknesses or drawbacks if applied, and in some cases purposing some improvements ideas that helped to guide our future investigation work. The result of the discussion phase is covered in section V.

E. Conclusions and Refine

The aim of this final step is to conclude the accomplished work and propose a set of improvement goals for the tools and technologies discussed in the review. The result of this phase is reflected in section VI.

III. TYPES OF MULTIMEDIA RESOURCES

Based on the review methodology described previously, in this section and the next we report on the review findings. In this section we first present different types of multimedia resources for education.

Multimedia information [21] refers to a set of different basic types of content, such as text, audio, images, animation and videos. Each of them requires different data representation for storage and transmission. Text resources are in general easy to create and occupy less disk space, while images, audio and videos requires more storage space and are more difficult to create. Animations should depend on the technology used to create and reproduce them [22].

There are many different formats to represent these types of basic multimedia resources [22], and also different tools to create them [23]. Text resources for example, can be created with different word processors, and can be stored as plain text, as a proprietary format (for example .doc), as standard format (for example .rtf or .pdf), etc. For storing images, audio and video there are a set of common formats (for example .jpg, .gif, .png for images, .wav or .mp3 for audio, and .avi, .mov, .mpeg, .mp4 for videos), and in the case of audio and video a set of codecs may be used to reduce the length of the original source [11]-[13]. Creating images, audio and video require specific devices to capture them (photo camera, microphone, video camera, etc.) [24] as well as specialized programs to edit them. Finally, animations require specific technologies and tools, like Flash [25] or Silverlight [26].

Basic multimedia types can be combined in order to construct new composed multimedia resources [27], [28]. For example, images or videos can be included inside digital text resources, such as guides or theory materials in order to exemplify or clarify concepts [29], [30]. Furthermore, a course merging different types of multimedia resources can be created using a SCORM structure [31]. However, for specific purposes, such as education, there is the need of creating more complex multimedia resources. Next, we present a taxonomy of the most known multimedia technologies currently used for education purposes.

IV. MULTIMEDIA-BASED APPROACHES TO SUPPORT E-LEARNING

The incorporation of multimedia techniques into education processes as a way to improve and enhance e-learning is currently an active research topic with any works in this area covering different aspects or learning technologies. In this section, a representative set of those works are covered, classified and reviewed by their learning focus.

A. Collaborative learning

Collaborative learning tools, and Computer-Supported Collaborative Learning (CSCL) environments, enable users to collaborate in virtual environments using tools, such as forums and chats, to share questions, problems, solutions, etc. As mentioned in [40], there are some systems that extend CSCL
capabilities with multimedia technologies, including TeachScape\(^2\), CoVis\(^3\), TurboTurtle [42], LessonLab\(^4\) or CSILE [43]. It is also worth mentioning the LangBlog tool, which is used to support language studies by providing a forum-based tool, where posts can be either textual or multimedia (audio or video) [44].

Synchronous collaboration tools can also be considered in this category, especially videoconference environments. There are many generic tools for this purpose like Skype\(^5\), WebEx Meeting Center\(^6\) or Adobe Acrobat Connect Professional\(^7\). In [45] a comparative between different videoconference systems is presented. Though being out of date it gives a view of the capabilities of such tools applied to e-learning. There are also some studies about the implementation of video-conference tools and techniques into e-learning, such as [46], [47] and [48].

Moreover, there are certain tools related with collaborative learning but focused on a different perspective. This is the case of the Virtualized Collaborative Sessions (VCS) system developed within the ALICE European project (http://www.aliceproject.eu/), and described in [49] and [50]. The VCS provides a framework that extracts knowledge from existing collaborative environments (such as forums) and converts this information into a multimedia interactive learning object. The content is created automatically and can be also edited by teachers, who can add and extend capabilities of assessment and provide emotional feedback among others. VCS’s major benefits include to reuse knowledge, engage learners by the use of multimedia interactivity, provision of authoring tools for teachers, and technical flexibility to extend the tool with new functionalities. As a main drawback, this system is developed in Silverlight which is not a standard technology and therefore less portable.

B. Learning management systems

Standard LMS, such as Moodle and Blackboard, include regular tools for working with multimedia resources (e.g. images, audio, video, etc.), but they provide multimedia tools for specific purposes to allow for user interactivity in certain learning tasks. On the other hand, some approaches define the new general concept of MLMS (Multimedia Learning Management Systems) which are multimedia-centered LMS. There are many examples of implementations and studies of such kind of systems like [51], [52] and [53] where different approaches of MLMS are proposed and evaluated.

C. Authoring tools

In [54] it is reported that the difficulties to create (i.e. author) multimedia content is the main barrier for teachers to use these tools. There exist many professional tools to create videos, animations and other complex multimedia resources, but not all teachers have the appropriate skills to manage such type of tools.

There are some techniques for knowledge reuse and automatically generated content for reusing knowledge in collaborative sessions [28]. In [55] a system is described to generate multimedia presentations from a set of data. Other approaches tackle the problem of content creation by providing usable authoring tools that reduce the time and hardness of this task. A representative example is an authoring tool that allows for editing the learning objects automatically generated from a collaborative sessions [50].

Finally, some authoring tools allow for creating a multimedia structure from previously existing content (see [33] and [34] where the T-cube and the GECCO systems are described), allowing teachers and learning designers to create complex multimedia structures from existing multimedia resources. Other custom tools enable instructors to create multimedia resources more easily. This is the case of [58], which allows for creating digital multimedia content and [59], where an easy-to-use tool for creating multimedia presentations is described.

D. Massive Open Online Courses (MOOC)

Over the last few years we are witnessing the hype of the Massive Open Online Courses (MOOCs). MOOCs are defined as open, free, participatory and distributed courses, representing a new generation of online education, easily and widely accessible on the Internet and involving a large or very large number of students [60]. According to [61], the term MOOC came out in 2008 when George Siemens and Stephen Downes taught a course about connectivism, with the experimental use of an online free course on this subject. The experiment turn into a massive number of enrollments around the world (above 2000). From then, different prestigious universities in USA presented different initiatives and platforms in support for MOOC courses, including Udemy\(^8\), Udacity\(^9\), Coursera\(^10\), MITx\(^11\) and edX\(^12\).

Systems and frameworks for MOOC enable to create courses with lecturer notes and presentations and videos with lesson recordings. Almost everyone with an Internet connection can enroll on a MOOC course, download its materials and actively participate using collaborative tools, such as discussion forums. Courses include practical assignments and assessments, as well as academic support from an expert on the field.

MOOC systems have a lot of benefits since they provide access to education to many people around the world and enhance collaboration among them. There are some authors posing that MOOC will become a real alternative or even a substitution to traditional university courses [61], [63]. They argue, for example, that MOOC courses are cheaper than university courses both to learners and to teachers to maintain. However there is still a large way to go as there are many unsolved issues, such as how to grade and certificate knowledge acquisition, how to provide a useful evaluation.

\(^{2}\) http://www.teachscape.com/
\(^{3}\) http://www.covis.northwestern.edu/
\(^{4}\) http://thelessonlab.org/
\(^{5}\) http://www.skype.com/
\(^{6}\) http://www.webex.com/
\(^{8}\) https://www.udemy.com/
\(^{9}\) https://www.udacity.com/
\(^{10}\) https://www.coursera.org/
\(^{11}\) http://www.mitx.org/
\(^{12}\) https://www.edx.org/
system to assess not only knowledge but skills, or how to tackle with the reduced course completion rates.

E. Social media

The social media term applies to the use of communication channels (mainly internet) for the creation and maintenance of user groups or communities. Such communities allow sharing information or knowledge, and enhance social interaction. [64]. The spectacular growth of social media in the last years has changed the way people uses Internet and has brought a new way of social interaction.

The use of social media helps improving the relationships between students [65], who have a higher motivation to learn when learning content is exposed through a highly-interactive environment [66]. In order to apply this to e-learning, [67] proposes a collaborative learning platform with integrated social media tools like wikis, blogs, social bookmarking and media sharing tools among others.

There are also studies about the application of social media technologies to e-learning or to learning in general, for example [68] and [69] present studies about the use of Facebook by students and lecturers, and the engagement of the both via that social media.

However other sources found the use of social media useful only in some part. For example both [70][71] expose some doubts about the ability of the social media to enhance student’s inspiration or engagement, and [72] sees social media as a socialization mechanism by talking with friends about work or learning than a way to doing work or learn.

F. Storytelling and Game-based learning

Both storytelling and game based learning are currently two very active research fields. There are many works and tools in development for the creation and use of these kind of multimedia learning resources, ([73], [74]), describing two platforms, StoryTec and Scenejo respectively, for authoring interactive stories. Examples of game-based systems are [75], which presents an interactive game to learn about surgical management algorithms, or [77] presenting a game for training people about fire safety.

Other works describe authoring tools in general [78], or specifically define a framework to describe and implement game-based education resources (also known as serious games) [79] or [80].

G. Simulation

Multimedia simulation tools can be applied to many learning fields: medicine, security, physics, chemistry, aviation, computer science, etc. Simulations help the learner to face “real” problems inside a virtual and controlled environment, so they can gain practice as if they were in a real-world situation. There are many works about simulations, such as [81] and [82] to mention just a few. These works present eLearning tools for physics simulation [48] present a specific simulator for teaching about electromagnetism while [49] presents a generic system for physics simulations. Similarly, in the medicine field, there are specific tools [83], [51], where both generic and specific systems for teaching about anesthesia are presented.

H. Other tools and technologies

From the great evolution of mobile devices over the last years, in terms of more powerful capabilities and widely availability, this opens the door to the development of custom applications focused on learning (e.g., e-books, learning activities, dictionaries, lessons planners, and a large, etc). However, the development of such applications is typically non portable because of the disparity of platforms and programming languages for that purpose. To remedy this situation the use of standards, such as HTML5, are spreading out in order to help develop heterogeneous device applications and deploy them in different platforms [85][86].

Finally, there are many teaching innovation projects related with the implementation of multimedia technologies into learning activities. This is the case of [87], where the aim is to transform the teaching resources from a master course into multimedia resources with interactivity capabilities, or [88], where the aim is to create a new kind of didactic resource in the form of an interactive multimedia simulator, among other projects.

V. Discussion

Based on the review work reported in the previous sections, we turn now to discuss on how multimedia technologies can influence e-learning, and then propose a set of issues and open questions to be shared with the research community. We organize this section in a list of discussion topics.

A. Use of interactive multimedia resources

The use of interactive and engaging multimedia resources improves the learning experience. It is a known fact that reading pages and pages of text is tedious and requires a lot of concentration. Moreover, mixing text with additional resources, such as images and tables facilitates the absorption of knowledge. Multimedia resources go a step further so that knowledge can be expressed in a more interactive way and closer to the student. Using video, audio, interaction, and other multimedia resources increases motivation and engagement in learning and enhances the understanding of the content.

B. Authoring multimedia tools

The use of better or simpler tools for creating multimedia resources may help teachers to consider this class of materials in their lessons [3]. The largest impedance in the use of multimedia resources for teaching is the complexity of creating such resources. If we reduce the effort required to create them providing support tools, then maybe more teachers would decide to use/create multimedia resources because of the benefits they provide to the learning process.

C. Multimedia tools for collaborative and social learning

The existing knowledge stored in collaborative sessions as forums or blogs can be reused and transformed into attractive and interactive media with extended capabilities as evaluation, automatic categorization or emotional control. The social knowledge they contain can be extracted, processed and turned into an interactive multimedia resource that can be used as learning material attractive for students.
D. Standards and specifications for multimedia tools

The use of standards, specifications and platform-independent technologies can help in spreading the use of multimedia resources as learning resources. The fact is that working with proprietary or non-portable technologies the content is only accessible for those teachers and students who are eligible to use them. Providing more portable resources would be useful to reach a wider audience.

Examples of multimedia standards and technologies wide spread are HTML5, CSS3 and JavaScript which are defined by the W3C (World Wide Web Consortium) for the creation of rich web pages [89], or video coding standards, such as the H.264/AVC [90] (aka., MPEG-4 part 10). Other standards like SCORM [91] can be used to combine and organize multimedia content into more complex and structured learning objects.

The definition of new specifications for the development of new multimedia frameworks or tools should be based on such standards like the case of the work presented in [92] which describes a new specification for the common representation of collaborative sessions called CS² (Collaborative Session Conceptual Schema) [49] which is based on the following standards: Semantically-Interlinked Online Communities (SIOC), Friend of a friend (FOAF) and DublinCore. Furthermore a new specification is also defined for complex learning objects structured as storyboards called SLO and based on the XML standard.

VI. FINDINGS AND NEXT GOALS

In this last step of our methodology, we summarize and extract from the above discussion the main findings, which in turn set the goals to achieve in order to improve the adoption of multimedia resources in e-learning activities. These goals will conduct the next iteration of this review study (see Fig. 1):

- Provide and improve multimedia educational resources to create easy-to-use authoring tools in order to simplify the efforts of teachers to generate and increase adoption of such resources.
- Automate the reuse of knowledge and transformation into interactive multimedia resources, to prevent loss of collaborative knowledge (as the knowledge generated in collaborative tools) and to simplify the process of creating multimedia resources.
- Adapt existing non-portable multimedia tools to independent platform technologies and standards to ensure portability and availability to more public.

Based on these findings we have developed an initial approach of a software platform to support multimedia technologies for e-learning [92]. The platform helps create and manage advanced e-learning tools and materials that meet challenging pedagogical requirements in online collaborative learning, such as increasing student’s engagement and learning performance during the collaboration.

The proposed framework (see more details in [92]), incorporates the findings of this survey in different ways:

- The automatic creation of advanced learning objects from existing collaborative sessions increases the reusability and eases the creation of such learning materials.
- The incorporation of multimedia resources and the use of extended techniques like assessment or emotional feedback, increases student’s engagement and performance.
- The provided authoring tools reduce the effort of creating new learning resources.

Finally, it is worth mentioning that the platform specifications are based on learning standards [49] in order to improve portability and ease integration with other learning tools.

VII. CONCLUSIONS AND FUTURE WORK

In this paper, a study of current use of multimedia technologies for e-Learning has been shown. We have explained the benefits of using multimedia resources applied to e-learning activities, but also stated the problems that impede the adoption of such resources in many cases. In addition, we studied the most important types of multimedia resources and the current multimedia-based approaches being used in e-learning activities. Finally we discussed the main issues and open questions of this study and proposed some goals to achieve, which in turn open some future directions of our research, as follows:

- To reduce the effort to create and manage multimedia resources.
- To promote the reusability of existing knowledge.
- To generate automatically multimedia-based resources from existing content.
- To increase the use of standards and portable technologies.

On-going work is to continue the development of the software platform presented in the previous section and we plan to use this platform in real e-learning contexts to support on-line courses and in-class assignments and eventually enhance learners’ engagement and improve the overall learning experience.

REFERENCES
