Towards Universal Game Development in Education

Automatic and Semiautomatic Methodologies

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Abstract. Serious games are increasingly being used in education to support the development of skills that future professionals and citizens require. However, the inclusion of games in the curricula can threaten the universal right to education for students with disabilities if they are not designed to be accessible. In this paper we discuss the need for tools that assist educators and educational content providers in producing games that are equally accessible for all. The goal is to minimize the cost and effort needed for introducing accessibility in serious games. We discuss to what extent the process of making a serious game accessible can be automated and supported by software tools that minimize human intervention. We conclude that there is a set of common accessibility barriers, especially those related to interaction and physical disabilities, that can be addressed systematically in a high proportion and therefore could be dealt with by software. Other problems, especially those more close to structure, storyboard and design, still need direct intervention from the game authors, but could be facilitated with appropriate methodologies and auditing tools.

Keywords: accessibility; educational games; serious games; universal design.

1 Introduction

Education is a universal right, and this adds an imperative to consider accessibility as a high priority requirement whenever new technologies are brought into the educational process. Otherwise we may be threatening the equality of opportunities for all students. This should be the case of educational games (a.k.a. serious games), which are rapidly gaining acceptance, and will probably become a relevant educational tool for enthusiastic teachers in the next few years [1]. But actual level of accessibility in videogames (both commercial and educational) is still low compared to other kind of technologies and digital static contents like the web [2].

adfa, p. 1, 2011.

One of the main arguments to explain the few attention that accessibility receives in games is that it means an extra burden for the developers and an increase factor of the investments. Firstly, design complexity increases. Games are intricate, heterogeneous and highly interactive applications that provide unique experiences depending on who is playing and what title is being played [3]. Designing an engaging, appealing and meaningful game for a wide number of users is an art that requires loads of expertise and creativity. When designers have also to cope with the special needs of users with disabilities the difficulty of the job increases substantially. And secondly, developers are faced with extra implementation challenges. Dealing with accessibility usually requires integrating (or even developing) complex and expensive technologies, such as text-to-speech or voice recognition. And it may even require producing special hardware (e.g. adapted game controllers).

All these overheads may be affordable for large entertainment game development projects, and even then most entertainment games tend to ignore accessibility concerns. However, educational games do not typically have large budgets, with many initiatives being led by enthusiastic educators and organizations with little resources. To avoid leaving accessibility concerns out of these projects, making accessible game-based educational content should be as seamless and cost-effective as possible. To accomplish this goal, we advocate for making the process as automated and straightforward as possible, limiting human intervention when possible in order to alleviate the cost overhead. To achieve the objective, it would be necessary to integrate accessibility tools and technologies in educational games development software, thus facilitating the implementation of accessibility features. This would facilitate design by providing game authors (i.e. educators) with reusable components and interfaces that are ready to use, resulting in significant savings.

This paper aims to answer the question of to what extent the introduction of accessibility in educational games can be automated. We build on our previous experiences developing accessibility solutions for educational games that we have tried to integrate in the eAdventure game platform.

2 Related Work

2.1 Approaches to Accessibility in Games

Traditionally, accessibility in games has been addressed individually in most of the cases, either adapting a specific title to meet the needs of a particular user profile [4–6], or developing games for a specific community of users with disabilities [7–9]. Audio games, for example, are designed for users with a visual disability [10]. However, other approaches have adopted a more general and holistic perspective, proposing frameworks and methodologies that consider the needs of different profiles of users that could also be applied to different types of games [11].

For example, in [12] the authors propose Unified User Interface Design, a methodology for designing universally accessible games where game tasks are devised without considering a specific modality or interaction device. In further design phases, alternative interaction methods are designed for each task depending on the needs of the target audience. Therefore the game design is extensible, facilitating the subsequent inclusion of accessibility features to cater for the needs of other users.

2.2 The eAdventure Educational Game Platform

eAdventure [13] (formerly <e-Adventure>) is a game authoring platform especially oriented to education[1] [14]. Although eAdventure's capabilities support the creation of a variety of 2D games, it was originally focused on point-and-click adventure games. This decision was driven by the consideration that these are the most appropriate genres for education because of their strong narrative underpinnings and predominance of reflection over action [15]. From an accessibility perspective, this genre does not pose barriers such as time pressure or fast-paced action, although a variety of barriers related to modality remains (they are highly visual, require moving a mouse for identifying objects, etc.).

There are two components in eAdventure: a game editor used to create the games and a game engine, used to run them. The typical workflow is to create and test the games with the editor, and then use editor's exportation features to produce a distributable package bundling all the assets that the game engine needs to process the games, which are a set of XML documents that describe the game and art resources (images, sounds, videos, etc.). The game editor includes education-oriented features and tries to simplify the game creation process as much as possible.

The game universe in eAdventure games is defined by composing elements of different types: characters, items, active areas, and the game scenarios (a.k.a. scenes), which are composed by a 2D background image and a set of interactive elements.

3 Experiences Developing Accessible Interfaces with eAdventure

We have used eAdventure to explore the automatic generation of accessible interfaces for two games that we present in this section as case studies. Upon the eAdventure source code, we built components that adapted the user interface depending on a given user profile. In this section we will elaborate on the level of automation achieved in each case. For each case, we have evaluated the usability from the end user's perspective, by asking different users to interact with each type of resulting accessible interface. Further technical details on the implementation of these interfaces can be found on previous publications [17, 18].

The official eAdventure distribution complies out-of-the-box with a certain level of accessibility for users with hearing disabilities, as all the information provided by audio can also be displayed with text. It is also accessible for users with a cognitive disability as it integrates an adaptation engine that allows game authors to tailor the game experience to each user capabilities (e.g. alternative contents or puzzles or skip-

[1] http://e-adventure.e-ucm-es

ping complex parts). For that reason, our work has focused more on improving accessibility for users with visual and motor disabilities.

3.1 Fully Automatic Adaptation of Interfaces - The case of 1492

In a previous work we have described a prototype built upon eAdventure v1.0 [18] that supported alternative modalities through a combination of input and output modules. Two user profiles were considered: blind users and users with a motor disability. Among the wide variety of levels of visual impairments, we characterized the blind user profile as users that needed the aid of screen reading software to use a computer. We considered users with a motor disability as those needed of using voice recognition software to interact with a computer due to reduced or lack of mobility. Both user profiles encounter barriers when interacting with point-and-click applications as they are not able to use the mouse.

The game author was only allowed to enable or disable the modules during the exportation process. All the adaptation to the user profile was performed automatically by analyzing the game description XML files and art resources (see **Fig. 1**).

The results were two new modalities which had common inner workings. The interaction was performed through short commands formulated in natural language (e.g. "grab the notebook" or "talk to the character"). An interpreter received the commands, executed them if they were correct, and provided feedback about the results using the appropriate channel for the active user profile (auditory for the blind user through a built-in text-to-speech engine, text for the user with a motor disability). Blind users introduced the commands using the keyboard, while users with a motor disability used speech.

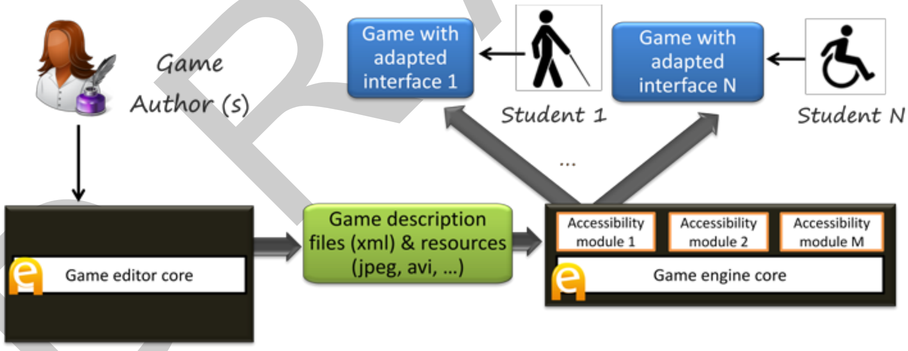

Fig. 1. Basic accessibility architecture. Accessibility was provided by specific input/output modules integrated with the engine, which are activated when the game was exported.

Command processing was directed by a regular grammar combined with a fixed list of synonyms for relevant verbs (actions) and nouns (interactive elements). The regular grammar was automatically generated from the description of the game, taking the actions defined for the interactive elements available in each game scenario. During game play, the number of actions and interactive elements available in eAdventure games is susceptible to change at any time as they depend on the value of a number of variables that vary dynamically according to the rules the game author specifies (this is the mechanism that eAdventure provides to define the game structure and flow). To deal with this issue the grammar was rebuilt each time an internal variable changed and also each time the scenario was reloaded.

This approach was applied to the 1492 game (available from the eAdventure website). It was evaluated by two users, one of each profile. Users were able to interact with and complete the accessible version of the game in the experiment (around 20 minutes of game play), but the system presented several usability flaws. The most important was that the user's vocabulary did not always match the system's vocabulary, defined by a list of synonyms that included at least 4 equivalent words for each keyword. As a result, command recognition accuracy was low, having little chances of succeeding if the game had taken longer to complete. Natural language processing techniques, combined with a well-defined ontology containing a wider vocabulary may overcome this type of issues. Such ontology could effectively cover most of the vocabulary related to actions, as these are common for most eAdventure games (e.g. grab, use, talk, examine, etc.). However, the nouns used for the game items cannot be anticipated as these are user-defined, requiring the game author to provide additional synonyms. Other usability problems found may be solved by improving the implementation of the system (e.g. delays in the auditory feedback generated).

3.2 Semiautomatic Adaptation - The case of "My first day at work"

Building upon the experience of the 1492 game, we conducted another experiment which resulted in the game "My first day at work", developed in collaboration with Technosite, a company of the ONCE (National Organization for the Blind in Spain) group. We refined the process to address the limitations found (see **Fig. 2**) by improving flexibility of the accessibility features that now could be configured with the game editor.

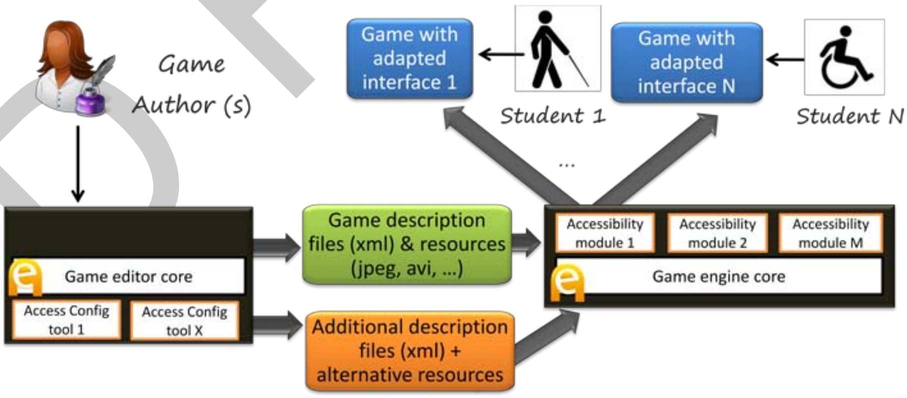

Fig. 2. Improved architecture and workflow. The accessibility features are now configurable from the editor to match different user profiles. The editor also produces automatically additional description files and resources.

In addition to the blind and motor disability profiles, a new user profile was considered: users with low vision. Colleagues from Technosite identified the adaptations this profile needed, which included screen and text magnification and use of a high contrast color scheme. Low vision users were expected to have problems to inspect the game scenes and find interactive elements as for them shapes and images blur with the background of the scene or with other elements.

We tried to keep the human work needed to accommodate the needs of these users to a minimum. The approach followed was to develop a low vision mode in the game engine. We started by developing an alternative rendering mode that improved the contrast of the interactive elements over the background of the game scenarios. This kind of technique has been applied to improve the accessibility of other games in the past [9], although focus has been placed on a single title instead of trying to build a generic and reusable system. This kind of adaptation introduced the novelty of modifying the rendering pipeline (i.e. how the game is painted), in contrast to blind users and users with a motor disability that required adapting the modality. The game engine automatically applied a light green filter to the interactive elements which increased their brightness and a dark purple filter to decrease the brightness of other areas, facilitating the identification of those interactive elements. Font sizes and colors used for cursors, buttons and menus were also automatically adapted.

However further adaptations were needed. Through early prototypes we found out that some scenes could not be adapted by automatically applying a filter, like those using images with text embedded. In these cases, authors should produce alternative graphic resources and include them in the game manually.

Although "My first day at work" was focused on meeting the needs of the three bespoken profiles (blind, motor disability and low vision), we also tried to make it accessible to users with cognitive disabilities (e.g. Down and Asperger syndromes). We wanted to explore the kind of adaptations these users require, who usually experience difficulties to understand complex language, memorize large pieces of information or present attention deficit disorders.

Dealing with these problems is much more complicated and there is little room for automation. The eAdventure adaptation engine was used to provide alternative paths in the game with different levels of difficulty, or alternative versions of text intensive components such as conversations.

The game was evaluated by 10 users with a disability (3 blind users, 4 with low vision and 3 with reduced mobility). Apart from minor usability problems that could be solved by researchers during the experience, all users were able to complete the game (around 60 minutes of game play).

4 Discussion

In the case studies presented the kind of adaptations that were required to meet users' needs varied across profiles. These adaptations affected diverse aspects of the game and were achieved with different levels of automation.

4.1 Level of automatic and semi-automatic adaptation

Table 1 shows a summary of the adaptations performed. Adaptations related to the modality, how the user interacts with the game or perceives the game feedback are prone to be automated (e.g. interfaces for blind users and users with reduced mobility). This does not mean that solutions are straightforward, but that current state-of-the-art in technologies like text-to-speech or voice recognition allows building interfaces that can be used by a high number of users. Once these interfaces have been built, they can be reused across different games with little extra work.

Table 1. Summary of adaptations performed for each profile. Table reflects what aspect of the game were affected and the level of automation achieved.

Profile	Aspect	Adaptation (s)	Automation
Blind	Interaction / modality	New interaction and adapted return of information	High
Motor disability	Interaction / modality	New interaction	High
Low vision	Interface / rendering pipeline	High contrast rendering filters, magnification, alternative images and color schemes	Medium
Cognitive disability	Game design and content	Lessened difficulty of puzzles, alternative version of texts	Low

Other types of disability require adapting how the game is rendered (e.g. users with low vision). The process can be automated to some extent, as the rendering pipeline in game engines can be configured to apply transformations over specific elements, like applying filters, using alternative color schemes (for example to deal with color blindness) enlarging images or providing a magnifier. However, there is a point where alternative versions of art resources may be needed, having a greater impact on the cost of the game. In the case of the game "My First day at work", it was necessary to produce 647 art resources in first instance, including images, animations for characters, videos and sounds. To make it accessible for users with low vision it was needed to produce alternative versions of 53 art resources, an increase of 7,57%. Although this value is not very high it could increase exponentially if more profiles were considered (e.g. users with color blindness), so it is important to keep the number of manually crafted alternative resources as low as possible.

4.2 Non-automatic adaptations and auditing tools

Other accessibility profiles (e.g. those related to cognitive disabilities) may not be subject to automatic adaptation and therefore are harder to address. The adaptations they require are related to the design of the game, which is difficult to analyze and modify without requiring the intervention of the game author. Some AI techniques could be explored to solve some of the problems, like using automatic text analysis to simplify the language used if the user has a cognitive disability, but it is unlikely to achieve similar levels of automation to those previously described in section 3.

In these cases other approaches could be followed. Game authors could be provided with tools to perform accessibility auditing over the games, following the guidelines of the W3C ATAG recommendation [19]. These tools would work as accessibility evaluation tools for the web, searching the game structure for potential accessibility barriers (e.g. complex language, too many interactions available in a game scene, use of time pressure, etc.).

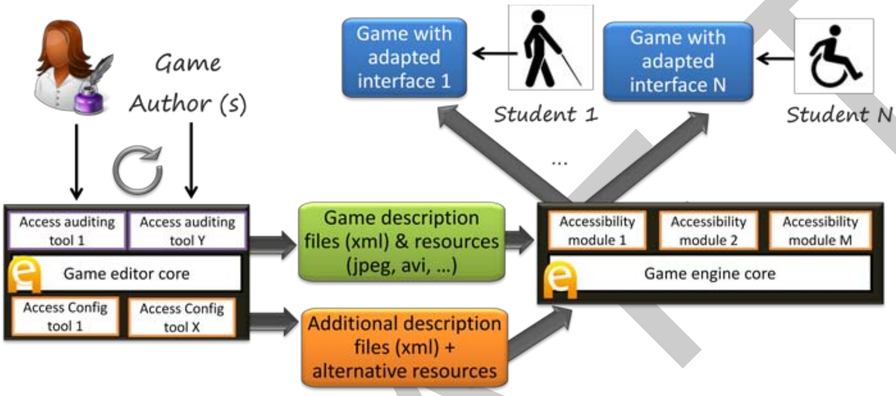

Fig. 3. Final architecture and workflow. Auditing and feedback tools are added, forming an iterative process of accessibility improvement.

An additional benefit of inspection and auditing tools is that they are educational, as they can recommend solutions to the game author and give further details about why problems encountered may endanger access for users with disabilities. The results of the auditing process could be presented in a human readable report, but could also be displayed in their context while the game runs to maximize the educational value. However, developing auditing tools is only feasible if the structure of the game is explicitly defined, as it is in eAdventure and most game authoring software, but not in game engines or frameworks where the game structure emerges or is implicitly defined. The final diagram of editing and running accessible games would look like the one **Fig. 3** shows.

5 Conclusions and Future Work

Educational games should be as accessible as possible to avoid a potential digital divide when they are brought into the classroom. To achieve this it is necessary to reduce the overhead needed to make the games accessible, especially in education where budgets are usually limited. Cost reduction can be reached by integrating accessibility tools in game development software. In this paper we have gathered different previous experiences creating accessible games with reusable tools, analyzing the strengths and limitations of each technical approach.

Based on these experiences, we have summarized the lessons learned during the process, ending up in the proposal of an architecture and workflow for the creation of accessible educational games. The focus of the study has been to identify what kind of accessibility adaptations can be performed automatically or semi-automatically, as these are the ideal approaches to keep the cost down.

We conclude that there are adaptations that can be performed mostly automatically, (e.g. generation of alternative interfaces) and have a significant impact in the accessibility of the games. Other adaptations can be performed semi-automatically, like having the tool try to create automatically alternative graphic resources (using filters and special rendering effects), and having a human provide alternative resources only in those cases when the automatic process was not enough.

On the contrary, when these processes cannot be automated, or when there is need for additional insight on the performance of the automated processes, we propose developing accessibility auditing tools to educate, detect barriers and propose solutions to improve the process of introducing accessibility. Nonetheless this is just a proposal that we expect to develop further in future research.

Finally, it should be noted that these automatic adaptations were designed specifically for educational games, where the tradeoff between cost and accessibility is critical, and accessibility should not be ignored. We consider that entertainment games may also benefit from this type of automatic and semi-automatic approaches, even though the game industry tends to favor specific developments for each game, due to the rapidly changing technology required to be competitive in that space.

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