Accessible Games and Education:

Accessibility Experiences with eAdventure

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Abstract

The increasing importance of the video games entertainment industry has prompted different efforts to promote the inclusion of accessibility features within games. Whilst the field of academia has produced relevant and promising results, mainstream producers are still reluctant to invest in access-for-all. However, in the field of academia there is also a growing trend towards introducing games and game-like activities into educational settings - usually labeled as '*serious games*' - in an attempt to explore other learning approaches and to improve the engagement of students. Yet while entertainment games can (arguably) opt to ignore accessibility, educational games *must* be inclusive and cannot afford to ignore it. In this paper, we present our approach to promoting accessible educational games. To reduce the barriers to and costs of creating accessible educational games, we explore the use of game creation tools with built-in accessibility features, as opposed to adding accessibility features *ad hoc* to existing educational games.

1 INTRODUCTION

Along with the increasing demand for improved educational processes, recent years have seen an increase in the application of new technologies and media formats to support new pedagogical strategies in order to prepare students for the challenges demanded by our rapidly changing society. Within the academic field of Technology-Enhanced Learning, there is an emerging trend to provide more dynamic and interactive content for students such as in the form of video games, which have been particularly highlighted because of their potential as learning tools (Gee, 2007; Kirriemuir & McFarlane, 2004; Michael & Chen, 2006).

However, the technology of video games is still an emerging and rapidly growing one. Other technologies - especially the Internet - have also experienced rapid expansion, but these fast-paced advances often entail a marginalization of people with special needs who cannot access digital content. This can be a consequence of a personal disability (e.g. blindness, deafness, reduced mobility, learning disorders etc.) or even be due to contextual and technological issues (e.g. noisy environments where sound cannot be heard or connectivity is limited, language barriers, etc.).

As a consequence, there has been increasing development of technologies that enhance the accessibility of information systems for people with special needs. Nevertheless, the creation of accessible technologies has been unequally focused on the different fields of software development. Whilst Web accessibility is reasonably well catered for, including multiple initiatives, tools, standards and guidelines, developers involved in other technological areas such as interactive multimedia (and especially video games) are still trying to find the most suitable way to create accessible products (Abrahams, 2010).

Focusing on the specific topic of games, whilst it is true that there are some video games that include accessibility features, the high costs involved in incorporating some of these features in the game post-production is hindering their widespread adoption. Moreover, some of the projects that include accessibility features have been introduced as a result of other motivations (e.g. including in-game voice command support to enhance the gaming experience). Commercial games tend to pay little attention to these accessibility issues, partly because the industry perceives that the return on any investment is marginal. Due to a lack of specific regulations governing accessible commercial games, many publishers opt to ignore the aspect of accessibility.

However, when we focus on educational games, these problems and the discussion relating to the potential return on the investment budget must be examined differently. The need for enhanced accessibility in any kind of educational content is more pressing than in developments that are purely entertainment-driven. According to a recent report on disability jointly produced by the WHO and the World Bank, more than a billion people in the world today experience disability (World Health Organization, 2011). According to this report, the estimated number of children experiencing "moderate or severe disability" ranges from 93 to 150 million, depending on the survey. If educational video games are to play a role in education, accessibility must be considered.

Accessibility for educational video games needs to address a diverse range of issues. Video games provide engaging experiences that are far more complex than other information systems which simply grant users access to data. As such, approaches which bring accessibility to the Web and other information systems are not fully scalable to video games, as these approaches may hinder the games' immersive and engaging atmosphere. In addition, when it comes to the educational field, it is harder to assume the higher cost of accessible games, given that most innovative educational gaming projects often have a limited budget. These contexts require methodologies, design patterns and tools specially devised to facilitate the creation of accessible educational video games. In reality, such elements are rare and have received scant attention in the surrounding literature.

The aim of our work is to facilitate the introduction of accessible features into the development of educational video games without compromising development costs. Integrating accessibility features into the tools used to create the games would free developers from having to implement ad-hoc accessibility solutions for their games. With this objective in mind, we have introduced a set of accessibility features into eAdventure, a game-authoring platform designed to facilitate the creation of educational *point-and-click* adventure games.

This paper is structured as follows: Section 2 presents some related work, focusing on the potential issues and current trends in the fields of accessibility, games and education. In section 3 we discuss some design issues especially relevant to educational gaming. Section 4 describes the accessibility features of the eAdventure platform. Section 5 presents a case study, in which a pre-existing game is enhanced with accessibility features and the approach evaluated. Finally, section 6 presents some conclusions and potential future lines of research.

2 RELATED WORK

The accessibility of information systems is rapidly attracting the attention of national authorities and IT professionals, since it is one of the potential sources of a digital divide. In this context, the accessibility of educational technologies can seriously affect the future opportunities of individuals who have limited means of access. While traditional teaching methods are often able to cope with aspects of accessibility through the efforts of the instructors, the current trend towards increasingly complex educational technologies is continuously increasing the challenge. In this section, we discuss the relevant topics for state-of-the-art accessibility in Technology-Enhanced Learning in general, and in particular in educational gaming.

2.1 Accessibility in e-Learning Environments

As e-Learning environments are mainly web-based systems (e.g. Learning Management Systems - LMS - such as Moodle™, Blackboard™ or Sakai™), the current state-of-the-art accessibility for e-Learning is very closely related to Web accessibility in general.

E-Learning environments have profited from the ongoing efforts of different public and private organizations to improve WWW accessibility. Highly influential organizations such as the W3C are presenting the necessary requirements for creating accessible web content through the Web Accessibility Initiative (WAI). WAI includes guidelines and techniques for the development and evaluation of multiple types of accessible applications related to the Web (W3C, 2002, 2008, 2011a, 2011b). Along with this initiative, different webmaster-oriented tools have been created which are devoted to checking the level of accessibility of web-based content and applications (W3C, 2006). Besides this, assistive technologies such as screen-readers or screen magnifiers have partially helped to improve the level of accessibility of the Web.

There are also initiatives that specifically deal with digital educational content for web environments. A very thorough approach was undertaken by the IMS Global Consortium in their IMS AccessForAll set of specifications (IMS Global Consortium, 2003, 2004). This initiative tries to define a set of data to describe the needs of students with disabilities and to tag the materials (Learning Objects) accordingly. The content that is delivered to the students could therefore be aligned with their special requirements. A similar approach is the ISO/IEC 24751-1:2008 standard, developed by the International Organization for Standardization (ISO). Other initiatives focus on the analysis of the level of accessibility of popular e-Learning systems (Freire et al., 2009; Minovic, Stavljanin, Milovanovic & Starcevic, 2008) or on enhancing accessibility of e-Learning systems (Sclater, 2008).

2.2 Special and Adapted Game Devices

The most common approach to increasing the accessibility of video games is to seek their compatibility with assistive technologies (Kearney, 2005). This includes compatibility with adapted and special hardware, but also with software. Some examples are screen-reading tools, mouse emulators and virtual keyboards. There are also tools that can be used to substitute the usual gamepads provided by game consoles (e.g. vocal joysticks, head gamepads or tongue sensors).

Following this line of research, the work presented by Sjöström & Rassmus-Gröhn (1999) shows the use of the PHANToM™ device as an example of how haptic devices (devices which provide human-computer interaction based on body movements and the sense of touch) can increase accessibility. This approach not only facilitates access to the games for a wide range of people with reduced mobility (controlling the video games with easy movements of one finger), but can also be useful for visually impaired people because the device offers them the possibility of perceiving 3D objects by means of the movements and vibrations it produces.

Another approach consists of adjusting games without requiring specific devices (e.g. adding subtitles). However, it is possible to bring both concepts together. For instance, there are games that allow the player to combine screen-reading tools, mouse emulators and virtual keyboards. In the same vein, we find auditory games (also known as "audio - games") (Friberg & Gärdenfors, 2004). These are games specially designed for people with visual disabilities where all the information from the game is transmitted via audio (Röber & Masuch, 2005). Specific sounds with special meanings are used intensively throughout the game so it is easy to remember the association between sounds and their meanings. In some of these games, the indications are given with abstract sounds, but the games most widely accepted are those which give users vocal descriptions reproduced through text-to-speech synthesizers. Other games receive input either vocally or by means of specific devices (Targett & Fernström, 2003).

2.3 Accessibility in Entertainment-Driven Commercial Video Games

There are some commercial video games that implement features to enhance accessibility from development or that have been modified after publication for this purpose. The creators of *Half Life 2*™ introduced accessibility for people with hearing problems during the development process after they received complaints concerning the first game of the series (*Half Life*™). The reason for this is that in *Half Life*™, certain information that was essential in order to complete the game was transmitted through cut-scenes (videos) without subtitles, making it impossible for people with hearing disabilities to reach the end of the game (Bierre et al., 2005).

Another example is *Terraformers*™, a game that was directly designed to include accessibility features from an early stage. It has a normal mode in which visual graphics are reproduced in the usual manner of first-person 3D games, but it also has an accessible mode. In the latter mode, sonar is activated to tell players what is in front of them and the graphic contrast is increased for visually-impaired people (Westin, 2004). This mode also allows the player to select objects from the inventory using voice commands.

Other academic papers have focused on providing guidelines about how to design interfaces or methodologies for accessible video game development (Friberg & Gärdenfors, 2004; Grammenos, Savidis & Stephanidis, 2007). As yet, there are no broadly accepted standards or specifications in this regard, but there are a few web-based initiatives that provide broad guidelines as to how to develop video games with accessible features. These initiatives must be translated into standards in order to unify the criteria and make the way to create accessible games more clear and facilitate the reuse of successful practices.

The International Game Developers Association (IGDA) has a Special Interest Group which focuses on accessibility issues. This group is active in producing state-of-the-art reports and analysis covering accessibility in games. One of their early works (Bierre *et al.*, 2004) provides a general overview of the field, covering what is meant by accessibility in games, why this is necessary, what kind of disabilities can be tackled at the stage of video game creation, and the most frequent adaptations that developers concerned with accessibility usually perform. The document also outlines how to adapt existing games to improve their accessibility through the addition of subtitles and customizing text fonts, and how the textual information and subtitles can be recorded or synthesized. Along with these ideas, the authors encourage the use of other approaches to gather user input, such as the use of voice recognition or other specific devices. However, the report does not propose any concrete patterns or methodologies for creating accessible games.

From a technological point of view, a unique approach is proposed by FORTH (Foundation for Research and Technology - Hellas), based on the Unified User Interface Design (UUID) (Savidis & Stephanidis, 2004). UUID proposes a design pattern where game tasks are initially considered in an abstract device-independent way. In later design phases, the interaction for each game task is designed, including the selection of input/output devices. Several games have been developed following these guidelines, achieving accessibility for people with a wide range of special needs. These are the universally accessible games (UA-Games). One example is *Access Invaders* (Grammenos, Savidis, Georgalis & Stephanidis, 2006), which supports different game settings depending on the potential disabilities of each player. These include blindness (in which case the game will be loaded with the appropriate characteristics of the Audio-Games), damaged vision and cognitive or motor disabilities.

As far as development tools are concerned, the market is populated with many authoring environments for the development of video games. There are development frameworks for game programming (such as Microsoft™ XNA™), game development environments which allow people without technical knowledge to develop their own video games (such as *Game Maker*™ and *Unity3D*™), and even simple editors oriented to specific game genres (such as *The FPS Creator* and *Adventure Game Studio*). However, none of these initiatives include pre-configured features which target game accessibility or which are oriented to facilitate universal design. Therefore, accessibility has to be implemented from scratch for each individual game and, depending on the flexibility and possibilities for expansion provided by the platform, it may eventually be unfeasible to introduce certain accessibility features (e.g. a text-to-speech engine is not available).

3 DESIGN STRATEGIES FOR ACCESSIBLE EDUCATIONAL VIDEO GAMES

Video games are very different in comparison to other materials (e.g. web-based content), as they pose accessibility barriers that must be thoroughly analyzed. Some of these can be addressed with a slight increase in development cost if they are considered from the beginning, but the investment may grow alarmingly if they have to be implemented *a posteriori*. For instance, a flexible configuration tool for the game parameters (font settings: color, size etc., audio settings, time response gaps and input/output settings) is something “cheap” to implement and effective for the accessibility needs of many common disabilities.

Other perspectives may be the importance of taking into account the compatibility with special or adapted game devices, or the importance of including special tutorials and documentation within the games (Bierre *et al*., 2005). Many different recommendations regarding the design of video games can be discussed, but in this section we focus on three issues that are especially relevant to educational video games: the choice of an appropriate game genre, the need for fine-grained adaptation support and finally the distribution and deployment of the games.

3.1 Appropriate Genres for Accessible Educational Video Games

Accessibility requirements are very different depending on the game genre. Moreover, not all game genres have the same educational potential.

In order to make them accessible, game experiences must be designed abstractly without committing to any specific device or input/output system. Therefore, where possible, it is better to focus on game genres in which engagement and immersion are obtained thanks to the attractiveness of game tasks, activities and the flow of the game itself, rather than from features such as the game being visually attractive or providing intensive action. Educational games must capture the attention of students and motivate them even when their accessibility features are activated. Otherwise, their positive effects on learning will evaporate.

Point-and-click adventure games, such as the classic *Monkey Island* and *Myst* sagas, meet these requirements. This kind of game captures the player's attention by developing an engaging and motivational plot that players uncover as they advance through the game. Elements such as graphics, sounds and special effects are also part of these games, but only as peripheral features to enhance immersion. They promote reflection instead of action, something which is very convenient for people with motor disabilities as it allows them to solve puzzles with no time pressure. As such, *Point-and-click* adventure and story-telling games are particularly appropriate for education (Dickey, 2006).

3.2 Fine-grained Adaptation vs. Coarse-grained Adaptation

The adaptation performed on a game to make it accessible must be fine-grained, that is as finely-tuned to each player as possible. Whilst relying on stereotypes may solve some of the problems, they may exclude some users. If different alternatives may be applicable in the case of a certain student, the optimum option must be always the choice, whilst considering aspects such as which alternative best preserves the engagement and immersion factors of the game or which will make interacting with the game less difficult and/or time-consuming. This approach differs from typical coarse-grained approaches to web-based content which are built on rough categorizations of students according to their disabilities. As opposed to with other kinds of content, within video games it is possible to provide much more finely-tuned adaptive experiences (Houlette, 2004; Magerko, 2008).

3.3 The Distribution and Deployment of Educational Video Games

The processes of delivering, installing and running games must also be accessible. This presents an extra burden in educational settings. Video games usually consume a lot of machine resources and require top-of-the-range computers that are not always present in schools. To tackle this, we could take advantage of current e-Learning systems to ease game delivery and distribution (Torrente, Moreno-Ger, Martínez-Ortiz & Fernández-Manjón, 2009).

Accessing a game that is embedded in a webpage would be easier for students with disabilities, as it does not require any additional setup and they usually have hardware or software aids with which to navigate the Web. This sets a design restriction on the games, as they have to be web-deployable (e.g. using Java technologies or Adobe Flash) and small in size in order that they can be easily distributed via the Internet.

4. THE eADVENTURE APPROACH

eAdventure is an educational game platform developed by the <e-UCM> research group at the Complutense University of Madrid (Spain) which has been used in the development of different educational games (Moreno-Ger, Blesius, Currier, Sierra & Fernández-Manjón, 2008; Moreno-Ger et al., 2010). The platform is composed of two applications: a game authoring editor (used to create the educational games) and a game engine (used to execute these games). The editor is instructor-oriented and does not require any technical background or programming skills.

Before beginning this work, the eAdventure platform already had some features that could facilitate the development of accessible games, especially for e-Learning applications. Firstly, it is focused on the *point-and-click* adventure game genre. Secondly, an audio file can be attached to any text string in a conversation. Thirdly, eAdventure includes mentoring mechanisms to help students when they become stuck on puzzles or other challenges. Finally, eAdventure allows the configuration of aspects such as the time at which each message is displayed.

In addition, eAdventure provides instructors with special features that enhance the educational possibilities of the platform, including mechanisms to track the performance of each user and to adapt the game experience to the needs of different students (Torrente, Moreno-Ger & Fernández-Manjón, 2008). Finally, eAdventure games can be deployed via the Web and integrated into a Learning Management System such as Moodle™.

In the following sections we describe the modifications made to the platform to facilitate the development of accessible educational games. The goal of developing this prototype was not to provide a holistic accessibility solution, but rather to investigate the feasibility of implementing accessibility in a game platform directly at the authoring tool level. Multiple simplifications were therefore made, targeting some of the most common disabilities: blindness, deafness, reduced mobility, low vision and some cognitive disabilities.

4.1 Combination of Input/Output Modules

The eAdventure platform includes different pre-configured input/output modules to facilitate the inclusion of accessibility in the games. The idea is that game authors should be able to include multi-modal interaction in their titles in order that people with special needs can play them easily by simply using functionalities included in eAdventure. In addition, eAdventure provides a number of in-game tools that can be included in the games as extra accessibility aids. These modules can be activated/deactivated automatically at the author's discretion.

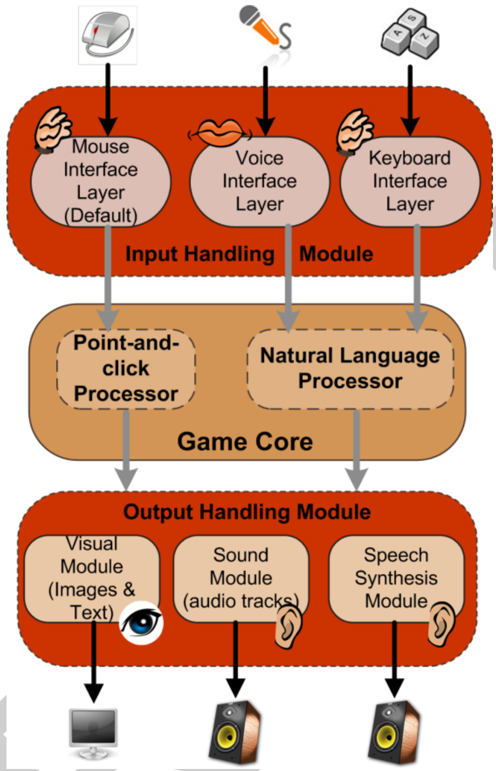

Figure 1: The architecture of the eAdventure game engine, with separate layers for input and output.

The eAdventure game engine is organized into three layers, with a core layer that handles the game interactions and monitors the state of the game and two separate layers which handle input and output. When the game is launched, it is possible to enable different modules within the input/output layers, selecting the most appropriate combination for the specific needs of each user.

The game core has two separate modules to influence and report the internal state of the game. There is a classic *point-and-click* input processor that was originally available in eAdventure. This processor is capable of handling mouse interactions, drawing on-screen graphics and managing simple sound effects. There is also a new Natural Language Processor capable of receiving audio or written input, processing it according to a regular grammar that defines valid commands for the game and using it to modify the state of the game. This module can also produce language output, using pre-recorded audio tracks or a speech synthesis module.

4.2 Input Modules

There are three input modules supported by the eAdventure platform: the Mouse Interface Layer, the Vocal Interface Layer and the Keyboard Interface Layer.

The Mouse Interface Layer is the classic interaction mechanism of *point-and-click* adventure games already present in eAdventure. Using this interaction mechanism, students usually need to point the mouse over the characters and objects they find as they proceed through the game in order to trigger any kind of in-game interaction. Students therefore need to be able to move the mouse over the screen to discover interactive elements in order to play the games, which may render them inaccessible to students with visual or mobility disabilities.

The Vocal Interface Layer was implemented to allow students with reduced mobility in hands to control games using speech commands. Using a microphone, students can directly "give orders" to trigger any interaction in the game (e.g. "go to the library" or "grab the notebook"). The Keyboard Interface Layer accepts the same orders as the Vocal Interface, but uses the keyboard as the input device. When this layer is activated, a text box appears at the bottom of the screen to allow the user to input commands. Students can thus interact with the game in their natural language, something which can be helpful for students with reduced mobility (using their voice) or visual disabilities (using the keyboard).

Table 1:

Example of natural language commands available during gameplay. Examples tagged with (1) would be dynamically defined for each scene. Examples tagged with (2) are common to all scenes and games.

Order	Description
Examine the table (1)	The game will provide a description of the object "table", if it exists in the scene.
Go to the door (1)	The student's avatar in the game will move towards the place "door".
Grab the pencil (1)	The game will take out the object "pencil" from the scene and put it in the student's inventory[1].
Use ingredient with mixer (1)	The game will combine the objects "ingredient" and "mixer"
Name items in the scene (2)	The game will tell the student which items have already been discovered so that he or she can interact with them.
Open options menu (2)	Pause the game and show the options menu.
Describe (the) scene (2)	The game will provide a description of the scene as a hint for the student.

Both the Vocal and Keyboard Interfaces were based on the same kind of interaction in order to reduce the implementation cost of the approach and improve the ease of maintenance of the system. Both layers are therefore connected to the same processor (the Natural Language Processor) which receives the commands and maps them onto the game semantic.

The regular grammar that defines game commands combines this kind of dynamically generated rules with some that are constant for all the scenes and games. These rules are used to define basic interactions with the game (e.g. open menus, exit game, skip dialogue lines etc.). Another important aspect is that in order to enhance usability, the Natural Language Processor accepts diverse synonyms for the verbs and nouns that are fixed (e.g. 'examine the

[1]The inventory is an element that is usually present in *point-and-click* adventure games. Players use the inventory to store objects they find on their way and keep them for a later use.

scene' or 'describe the scene' are both permitted). Table 1 shows some examples of typical orders the system would recognize in an eAdventure game.

4.3 Output Modules

eAdventure has likewise been provided with three output modules: the Visual Output Module, the Sound Output Module and the Speech Synthesis Module.

The Visual Module is not only used to display images on the screen (the background image for the scene, the characters and objects etc.) but also text. Text is a key element in *point-and-click* adventure games, as these games commonly provide information through conversations with other characters which are usually written on screen.

The visual module can also be enhanced with two additional features. Firstly, game authors can provide students with a screen magnifier. To avoid disrupting the immersive atmosphere of the game, this is represented as an object that is included in the student's inventory (Figure 2). The student can use it to turn the mouse pointer into a magnifying glass that can be moved around in the game. Similarly, the player can also activate or deactivate a special high-contrast mode that highlights the interactive objects and partially hides the background (Figure 3).

Figure 2: Example of the in-game “screen magnifier” tool in an eAdventure game.

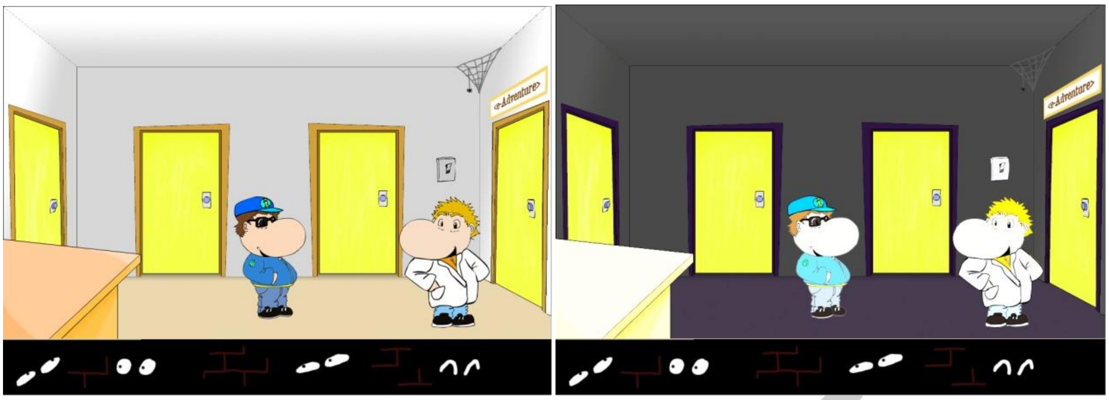

Figure 3: A game scene in regular view (a) and in high-contrast mode (b).

In turn, the Sound Module is capable of playing pre-recorded sounds, and it is possible to use it to add accessibility features to in-game conversations and texts by recording all the dialogues (the sound module can play audio tracks in MP3 format). However, this significantly increases the cost of the game, requiring voice actors to record each individual utterance. This is often a problem when the budget is limited (as is usually the case for most educational projects).

This is where the Speech Synthesis Module can be a helpful addition, as it allows the introduction of accessibility for students with visual disabilities at a low cost. When this module is enabled, any text to be written on the screen will be automatically reproduced through the Speech Synthesis Module. Higher-budget projects can still use the standard sound module (which plays mp3 files) for increased sound quality. In either case, these modules can also read special accessible descriptions that can be attached to each scene in the game.

The regular Sound Output Module is also used to play descriptive sounds as an alternative feedback for the user. For instance, when the Keyboard Interface is activated and the user introduces a command, the system uses special beeps to indicate whether or not the command was a valid one. Analogously, other actions such as entering or leaving the options menu have been associated with other specific beeps.

4.4 Configuring Accessibility Features with the eAdventure Game Editor

The first step to create an accessible adventure game is obviously to design and develop the game with the eAdventure game editor. It is recommended not to leave the decision about accessibility to the last moment, but to instead think about the accessibility features that are going to be introduced in the game during the design phase. This is especially true if these will require adapting the game flow as this would involve providing alternative paths, dealing with difficulty settings or providing additional aids in some situations.

When the game is designed, the author must select the input/output modules and the in-game accessibility tools (such as the screen magnifier) that will be active in the game. The game editor uses these settings to optimize the exportation process so that no unnecessary modules will be packaged within the game.

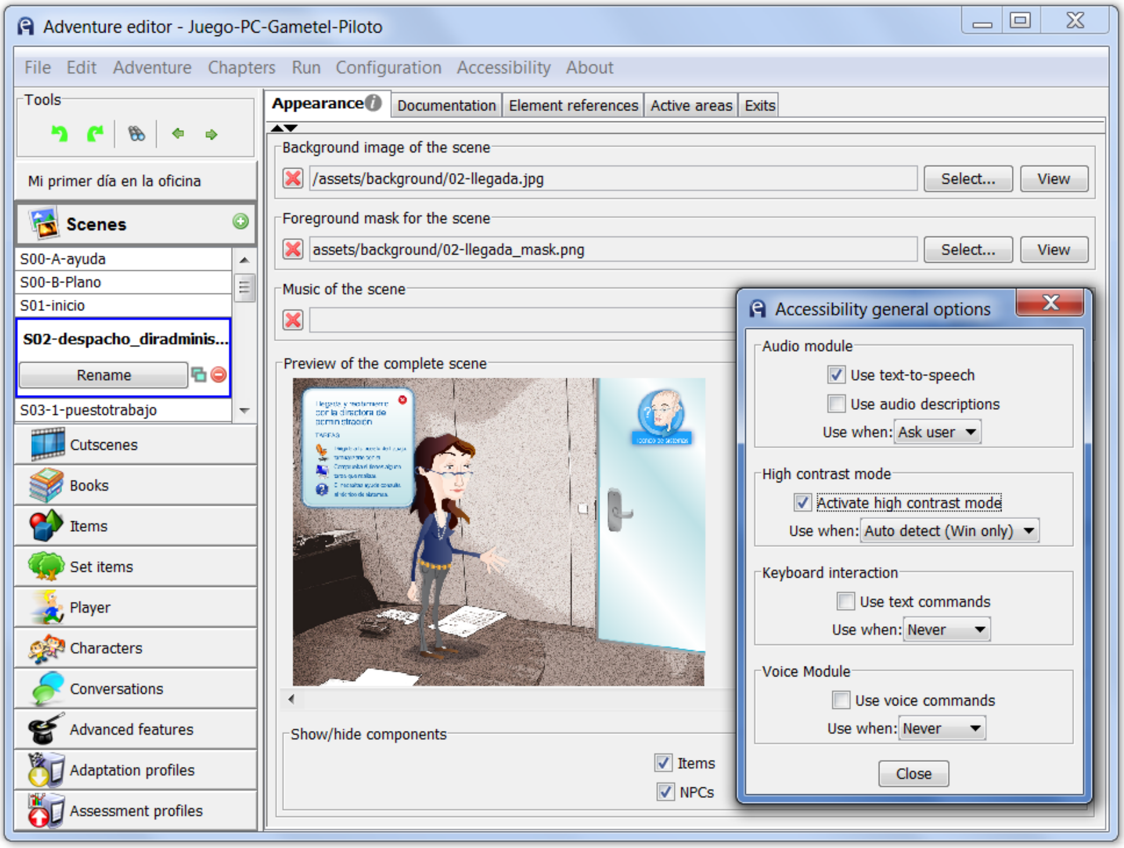

Figure 4: Edition of the Input/Output settings with the eAdventure editor.

If visual disabilities are considered, it is very important that all the visual elements of the game receive alternative descriptions. When the player enters a scene, the game engine will use these descriptions along with some extra information that it computes from the game definition (e.g. the number of elements in the scene) to create a complete description of what the student is supposed to see. The completed description is synthesized and played using the audio system. Authors can redefine this behavior by introducing a list of available descriptions for each scene and set the conditions that will trigger each description.

The next step is providing captions for cut-scenes (videos and slides). This feature is currently only supported for slide-scenes in eAdventure[2]. Finally, game authors need to create the game adaptation profile which will determine under what circumstances the game must be adapted, and how the adaptation must be carried out.

[2] A slide-scene is a special type of cut-scene that displays a sequence of static images, rather than full-motion video.

5 CASE STUDY

As a case study to test the new eAdventure accessibility features, we introduced accessibility into a pre-existing game. Following the ideas described in section 4, we introduced accessibility for people with different degrees of visual, auditory, motor and cognitive disabilities in the game *1492*, an educational game about Spanish History[3]. *1492* specifically focuses on the events that occurred in 1492, such as the Granada War and Columbus' expedition (Figure 5). These are notable events in the history of Spain and are thoroughly covered in primary education, which is a strong additional motivation for making the game accessible.

Figure 5: A screenshot from the game *1492*. Cristobalín is exploring King Boabdil's palace looking for the stolen ceremonial Key to the City.

[3] The original version of the game can be downloaded from the eAdventure game repository: http://e-adventure.e-ucm.es/course/view.php?id=26. Video produced by Spanish Public Broadcasting System, available on Youtube: http://youtu.be/ROg3pjnfi8U.

5.1 Adaptation of the *1492* Game

1492 was not initially designed as an accessible game. The first step was to decide the target disabilities and to then activate/deactivate the necessary input/output modules and/or in-game tools using the game editor. For this case study we considered visual, auditory, mobility and cognitive problems.

As cognitive disabilities are very complex and may require very different adaptations, we considered just two possibilities in order to test the system: students with low memory capacity and students with non-severe reasoning problems. In the first case we defined alternative conversations that lessened the amount of information that the student is required to gather at any one moment, thus increasing the focus on relevant information and reducing the amount of "superfluous" information. In the second case, we defined alternative game paths with simpler puzzles and riddles. Furthermore, the original *1492* game included an in-game multiple-choice examination at the end of the game by means of a conversation between the main character (a student called Cristobalín) and his teacher. For both types of cognitive disabilities, we provided an alternative, more linear exam.

In order to cover the rest of potential special requirements, the game is configured with all of the input/output modules and the screen magnifier. The high contrast mode was not used. To allow the modules to describe the game, we also had to provide alternative descriptions of the visual elements found in each scene, as well as of the scenes themselves, so that these could be passed to the speech synthesizer.

5.2 Preliminary Evaluation

The preliminary evaluation phase so far conducted involved two end users. In this session, the game was played for 20 minutes by a blind user and a user with reduced mobility in hands. Both users had prior experience interacting with computers both for work and entertainment (they liked to play some accessible video games). For the visually impaired user, the system was configured with the Keyboard Interface and the Speech Synthesis Module activated. For the user with motor disability, the Vocal Interface was activated as the interaction method. During the experience, we observed and documented the reactions of both participants. The most relevant conclusions obtained from this session are as follows:

The blind user had some initial trouble interacting with the game. Apparently he did not find the mechanism for interaction intuitive. He expected to be able to navigate through the game elements using the keyboard arrows and select the interactions from a menu as he would typically do when navigating the Web. After a while, he began managing to interact with the game without making major errors. In this regard, the auditory feedback provided by the system (speech synthesis and special sound effects) seemed to be appropriate. Nevertheless, it was sometimes difficult for the user to identify which character was speaking as not all the characters' voices were different. This person did not need any assistance from the researchers and could complete the game session on his own.

The person with motor disability had some initial problems with the pronunciation of the commands. It was noted by the researchers that the shorter the pronounced commands, the more efficient the voice recognition. Nevertheless, the user did not realize this and became quickly frustrated and he therefore required some help from the researchers to understand how he was expected to interact with the system. Following this, the accuracy of the vocal interface began to increase, allowing him to complete all the three scenes of the game included in the evaluation session plan (in the case of the second user, the full game was not tested in order to keep the session as short as possible). The main issue with the vocal interface was the vocabulary that the player needed to use in order to activate the game commands. As a result of this experiment, we realized that it is necessary to add flexibility to the vocabulary (e.g. introducing more synonyms from a thesaurus) for the different game actions.

6 CONCLUSIONS AND FUTURE WORK

The current trend in learning technologies is towards increasingly complex multimedia and interactive content and this presents a significant accessibility challenge. In this regard, while entertainment-driven games can to some extent afford to ignore accessibility concerns, educational games should be inclusive and available to everyone regardless of their individual conditions.

Nevertheless, the development of accessible games comes at a cost. In educational settings, with both limited budgets and markets, the problem becomes greater. In addition, accessible video games are a relatively new idea and the existing research in the field is still at an early stage. In this work, we have presented the foundations of our approach to accessible educational gaming, which provides a tool to facilitate the inclusion of accessibility features in educational video games.

However, the system is still at the prototype stage. The evaluation thus far performed has proven the feasibility of the approach, as end users were able to interact with the system. Nevertheless, the results obtained show that there are still open issues that should be dealt with before incorporating the features into a production environment. In this regard, according to the results of the evaluation, it would be necessary to reduce the learning curve, as end users become frustrated the first time they interact with eAdventure games using the vocal and keyboard interfaces. This may be solved by including further guidance and an in-game tutorial that explains how the user is expected to interact with the game. Once they are stable enough, we are planning to integrate the accessibility features described throughout this paper into the main release of the open source eAdventure platform for use by the general public. This will probably be when the second generation of the platform (eAdventure 2.0) is released, which is initially scheduled for late 2012.

Another aspect that will require further attention is the evaluation of our approach for users with cognitive disabilities. While the case study was designed to cope with some cognitive disabilities, it has yet to be tested with target users. Finally, further testing is required in order to measure whether the introduction of accessibility in the games had a negative impact on the user's immersion and engagement. While the users who tested the system felt positive about the experience, the engagement with the regular version of the game compared to the accessible one has not been formally evaluated.

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