Eyes-free Interfaces for Educational Games

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Abstract—**Any new technology introduced in the classroom has a potential risk of increasing the divide for students with disabilities. This impact becomes greater as the new complexity of new technologies increases. In this sense, one of the most complex technologies currently being considered are educational videogames. And while the potential benefits of videogames are great also pose significant challenges from an accessibility perspective. In this paper we investigate interfaces that may facilitate access to educational games for blind students. The long-term goal is to integrate these interfaces into educational game engines or authoring tools, facilitating the adaptation of educational games to avoid a future problem of digital divide. Three eyes-free interfaces have been developed: 1) a navigation system that allows the user to browse and interact with elements using arrow and action keys; 2) a sonar that helps blind users find interactive elements in the game universe with the mouse; and 3) an interface that interprets commands typed in natural language.**

Keywords-Accessibility, audio 3D, eAdventure, point-and-click interaction, eyes-free games, e-learning, distance learning, game authoring tools, game-based learning, online learning, videogames.

I. INTRODUCTION

Educational computer and videogames (from now on, simply referred to as "games") are gaining acceptance in academic forums as more and more empirical research and evidence about their educational potential are becoming available [1], [2], and also from educational institutions which are increasingly adopting game-based learning paradigms [3].

However, educational games pose a significant source of digital divide for students with disabilities, as the accessibility of this type of content is not well covered yet [4]. Accessibility of educational games should be improved in order to avoid a potential problem for teachers willing to use games, who may need to plan alternative activities and contents for students with a disability, with the consequent stigmatization for the students.

One of the main arguments used to justify the lack of accessibility of games in general is that it has a considerable extra cost associated. Most of this cost comes from the need to develop expensive interfaces for users that represent rather little percentages of the target audience, given the segmentation of adaptations needed by users with disabilities. For example, to make a game accessible for blind users, it is necessary to include an interface that allows interacting with a keyboard or Braille device and provides feedback with audio, while users with a motor disability may need a speech-powered interface.

To improve the accessibility of educational games we propose shipping configurable accessible interfaces along with educational game authoring tools [5]. This would help to make games more accessible without requiring additional efforts from game developers or educators.

Nonetheless, for this approach to be feasible, first it is necessary to investigate, from a human-computer interaction perspective, what type of accessible interfaces could be applied in different contexts and for different games. While research has been done in the last years exploring the design of game interfaces for users with disabilities, solutions still lack scalability as they are developed for specific games.

Accessible game interfaces should allow user-friendly and pleasant interaction but preserving elements that are central to entertainment and learning (e.g. immersion, challenge or engagement) for all users regardless of their abilities or previous experience. For example, if an accessible interface alters substantially the level of challenge of the game, enjoyment would be diminished, as there is a clear relation between an appropriate level of challenge and players' engagement [6]. The results would be a game with less educational potential, as engagement is a key element in games supporting active learning [7].

The purpose of this study is to investigate accessible interfaces that can deliver the best game experience to blind users with different abilities and gaming habits. To narrow the scope of the project we have focused on point-and-click adventure games, a genre that is especially suitable for education due to the emphasis on reflection and problem-solving instead of action and pacing [8], [9].

This paper is structured as follows: section 2 summarizes the state-of-the-art in designing games that are accessible for blind users. Section 3 analyses the

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point-and-click genre we are focusing on. Section 4 introduces the eAdventure gaming platform, which has been used as a base to implement the interfaces proposed, which are described in section 5. Section 6 provides a discussion about the interfaces developed and finally section 7 provides conclusions and future lines of work.

II. Related Work

Blind users are the community most affected by accessibility barriers in educational games, and therefore are one of the target groups that have attracted more focus from academic research [4]. They are also backed up from communities of practice that lead cutting-edge initiatives regarding accessibility in games, like AudioGames.net [10], or the International Game Developers Association (IGDA) special interest group on accessibility [11]. They have also done a very intense job in identifying accessibility issues in video games, as Bierre et al describes in [12] for example.

Many research contributions about game design and interaction for users with lack of vision explore the use of new senses to improve the game experience, especially haptic feedback. One of the first examples is the use of the PHANToM™ device to increase accessibility [13]. More recently this kind of technique has been applied, through different devices, to games like a 2D pong [14] or a Sudoku [15]. This kind of feedback has proven to be successful not only in computers but also in mobile devices [16].

Other publications investigate the use of auditory feedback to substitute the visual interface [17], [18]. For example, Atkinson et al. [19] introduce the idea of associating "earcons" to game elements. Directional audio [14], [20] and 3D sound systems have been used to orient users and help them locate static or moving elements in the game universe [21], [22]. For example, the project "The Sound of Football" combined mobile devices with a sonar-like interface to help users play football without using sight [23].

In turn, some other contributions have focused on making specific commercial games accessible after their release, such as Quake [19], "Dance Dance Revolution" [24], Rockband [25] or Guitar Hero [26]. Most of these approaches succeeded in delivering accessible and fun experiences to the target users. However, most results were very specific for a single tool or game, and it is not always clear how to scale and reuse the solutions proposed.

Other approaches have addressed design methodologies or implementation frameworks that are applicable to a broader number of games. For example, Grammenos et al. [27] introduce a unified design method that guide developers in producing more accessible games. It uses the concept of abstract tasks to make the games device and technology independent, and therefore can be more easily adapted to the needs of different users. Roden and Parberry [28] propose a game engine for creating interactive audio only games.

III. Point-and-Click Adventure Games

In this section we describe the point-and-click adventure game genre, which we have focused on in this study. The importance of these games for education is discussed, and interaction is described as a means to understand the challenge of introducing accessibility in these games.

A. The Genre

Point-and-click adventure games lived their golden age in the 90's, when titles like the "Monkey Island™", "Indiana Jones™", "Myst™" or "Day of the Tentacle™" sagas were easily found among the highest positions of the best selling games rankings. The genre lost attractive in the 2000's, at least among mainstream titles, but it still has a place in the independent (or *indie*) market and keeps an important community of users. Besides, the point-and-click adventure genre is receiving an increasing attention from academia because of its potential for serious and educational applications, due of its strong narrative underpinnings [9], [29], an aspect that is well aligned with learning [30].

From a Human-Computer Interaction perspective, it is an excellent representative of point-and-click interfaces and the barriers they pose, which are present in many modern games and applications. In classical adventure games, to find interactive elements in the game universe the user moves the mouse cursor around. When it hovers over an interactive element, some visual feedback is provided, meaning that the user can click it and then the game universe reacts (e.g. a character starts talking) or a contextual menu with available actions is displayed.

Therefore, the main problem that makes these games inaccessible for blind students is the need of use sight to explore the game world, which is also a characteristic present in other games. Nonetheless, point-and-click adventure games have some advantages as they lack many typical accessibility barriers, like a very fast pace or the use of time pressure to provide challenge [11].

B. Exploration in Point-and-Click Adventure Games Provide Challenge

An appropriate balance of challenge throughout all the game play is a key success factor in all games [6], [31]. In point-and-click adventure games a non-trivial mechanism to explore the game universe contributes to provide adequate challenge and make the game enjoyable. Any adaptation of the interaction aiming to improve accessibility must conserve this exploration process or the pleasure of the game experience may suffer.

Challenge helps the player to reach a flow experience where engagement, feeling of personal fulfillment and enjoyment are maximum according to Csikszentmihalyi's theory [32]. The difficulty of the game is usually designed to challenge the player's abilities but without surpassing them to the extent of becoming frustrating or unbeatable. Since players' skills are expected to grow as they play, so does the challenge provided. There are different strategies to provide challenge (e.g. time pressure), and most of the games use a different combination of these.

In point-and-click adventure games, challenge is provided by setting out non-trivial puzzles the player must solve by applying reasoning and problem-solving skills. The player needs to observe the game world, apply reflection, compare to past experiences and build on previous meanings [33] to reach the solution of the puzzles. Without these components enjoyment is seriously damaged.

Observation involves exploring the game universe to discover which valid interactions are hidden in a scene, which elements can be interacted with, how to interact with them and what are the expected consequences of these interactions. This process requires time, with players often wandering around and exploring at their own pace, trying out different things. It is not immediate and it is scaffolded as the game starts with just a little part of the game universe available and new parts are unlocked as players advance in the game. The game must subtly guide the player in this exploration and discovery process, but it must not be evident (it is important that the players use their own problem-solving skills to beat the game).

C. The Importance of the Story

Point-and-click adventure games use an attractive story to engage players, as opposed to other kind of games that rely on elements like striking visual effects and images [9]. From an accessibility perspective, game interfaces must allow every user to experience the story in a comfortable way to have a pleasant experience.

A strong narrative component is usually present in point-and-click adventure games. An appealing plot is unveiled while the player progresses in the game, solving different puzzles and riddles that are integrated within the game plot. This is how many of the most successful adventure games manage to keep players immersed and engaged. In terms of accessibility this is interesting as story can be considered as a neutral element (it is not bound to devices or technology) that may appeal to different players with different abilities, including blind and sighted players.

IV. The eAdventure Platform

The eAdventure platform is a game authoring tool that allows for the development of 2D educational games, with special focus in point-and-click adventure [34], [35]. It was designed to facilitate the development of educational games by people with little technical background (e.g. educators). It is compound by a What-You-See-Is-What-You-Get (WYSIWYG) game editor used to create the games (see Figure 1), and a game engine that can be distributed following the Learning Object Model to deliver the games to the students [36].

The game universe in eAdventure is defined by a number of 2D game scenarios that are interconnected using "exits"; that is, regions of the scene that can be clicked and that transport the player to a different scene (see Figure 1). Exits, along with objects and characters are the basic interactive elements supported by eAdventure. In addition, objects and characters support several types of interactions (e.g. grab, talk to, use, etc.).

The platform has already been used as a testbed for educational accessible game research [5], and the long-term goal is to integrate multiple forms of accessible interfaces in the eAdventure game editor and engine so they could be easily configured by game creators (i.e. educators) to adapt the games.

Both the author and the player would profit from having alternative interfaces available. The author (e.g. educator) could include several interfaces in a game, and decide which users would use each one depending on the design, special needs of the users, previous experience, etc. The author could also leave this decision to the user, who could choose the interface that she/he prefers, or even to the game, who could set up an easy interface in first place and suggest other interfaces as the user progresses in the game gaining expertise and skills.

However, in order to inform this process, it is necessary to understand the restrictions and affordances of different accessible interaction mechanisms. In this work we have implemented three alternative accessible interfaces for blind users. All of them have been built on top of the eAdventure platform, with the objective of identifying which elements of each interface provide value or limitations.

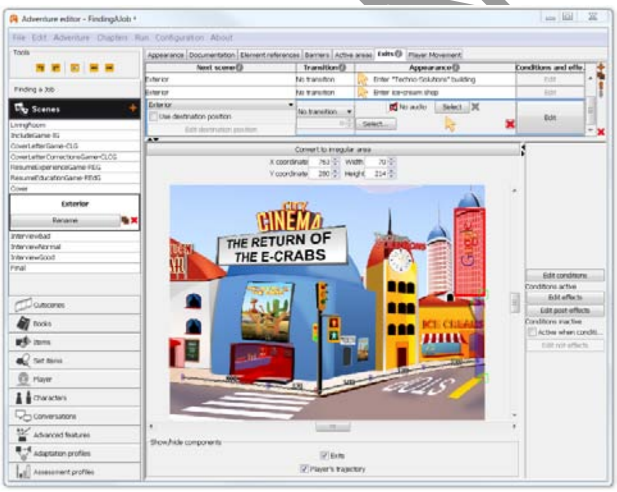

Figure 1. Screenshot of the eAdventure game editor, version 1.4. The red rectangle marks an exit defined on a game scene.

V. Three Eyes-Free Interfaces for Point-and-Click Games

Each eyes-free interface prototype developed provides a different experience to explore the game universe. To be more specific, we define exploration as the process from which the player obtains information about what are the available interactions on the scene (what can be done in it) and the more likely consequences these will have in the game world.

All the interfaces use the same system for providing auditory feedback. Each time the game universe changes an audio message is reproduced using the eSpeak free text-to-speech software. This includes, for example, entering a new game scene or triggering any interaction with objects or characters as defined in the game. The system is flexible, allowing the game author to define alternative messages for each specific interaction depending on users' performance and progress.

The flexibility of the audio feedback system helps to provide fine-tuned guidance to explore each game scene, keeps the user engaged in the story and contributes to create drama and tension. It is also used to provide a message describing the scene when the user moves from one scenario to another. The message changes depending on the number of times each scene has been visited.

Next subsections describe each interface: a cyclical navigation system that resembles how a blind user navigates through a web page using the keyboard; a sonar, which uses 3D audio to identify the location of interactive elements on the scene; and a natural language interface that interprets text commands written in plain language.

A. Interface 1: Cyclical navigation system

With this interface, interaction is similar to browsing the web using a screen reader. Available interactions in the scene are structured in a two-level focus cycle that can be navigated with the left and right arrow keys (see Figure 2).

The first level is compounded by the interactive elements on the scene (characters, objects, exits, etc.). The second level contains actions related to each element (e.g. talk to, grab, leave, etc). To access the second level, the user hits the action key (intro). To return to the first level, the user hits the go-back key (escape).

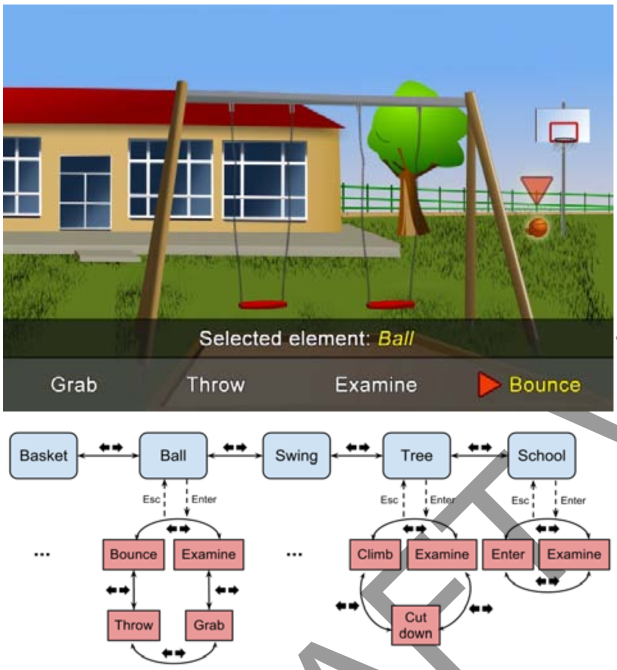

Figure 2. Example of navigation through elements of a game universe with interface 1 (cyclical navigation system).

This interface was designed to be as intuitive and natural for blind users as possible and should be perceived as the most usable since all actions are accessible within a minimum number of key strokes. However it is not expected to be very fun since the actions are presented to the player directly, turning game exploration into a trivial process.

B. Interface 2: Sonar

The purpose of this interface is to guide the player in finding interactive elements with the mouse, instead of using the keyboard. On the scene a 3D positional audio system is configured. In this system, each interactive element emits a different sound that can be configured. Information about the position of the element related to the mouse cursor is provided by altering the intensity and pitch of the sound. Depending on the distance of the element to the mouse cursor, the sound is perceived with a different intensity. Pitch is used to provide information about the vertical position of the mouse pointer (high pitch denotes that it is near an element, while low pitch denotes that it is far from it).

When the user hovers the mouse over an element, a confirmation sound is played using the audio feedback system. The user can also activate or deactivate the sonar with the space bar to limit acoustic fatigue. When the mouse accidentally exits the game window boundaries, a special sound is played. The mouse is relocated to the center of the screen each time the scene changes.

C. Interface 3: Natural language commands interface

With this interface interaction is articulated through short text commands formed in natural language that the user introduces in a little text box. After the command is introduced, the system tries to interpret it and match it to one of the available interactions in the scene, using a regular grammar that defines the structure of supported commands and a thesaurus of synonymous based in a previous work [5]. The user receives audio feedback about the results of this matching and if it has succeeded, the interaction is triggered.

The kind of feedback returned by the system after each command is introduced can be configured by the author of the game. By default, the system will return a random message (e.g. "Ummm ... I'm not sure what you mean" or "I think rather not to do so") depending on the rules of the grammar that caused the matching to fail. However, it is possible to use the flexible audio feedback system to provide hints if more guidance is required.

In contrast to interface 1, in this case the interactions available are not directly revealed to the user, but instead the player has to find them out by test-and-error of different commands.

This interface also supports a list of special commands:

- **Actions**: remembers the user all interactions that he/she had previously discovered in the scene.
- **Describe scene**: provides audio feedback about settings of the scene, combining an optional message introduced by the game author and a summary of the elements presented (e.g. there are two exits, an object near character A, etc.).
- **Help**: Provides hints and interaction instructions.

VI. Discussion

The three interfaces have different characteristics and may be adequate for different users and applications. In this regard, it is interesting to discuss how usability and entertainment varies across these interfaces.

Probably the most usable is Interface 1 (navigation system), according to a classic definition of the term, because it allows triggering interactions with minimum effort. Therefore, this interface may be suitable for blind students with little gaming background, or for games with an intense simulation component. It could also be useful for inexperienced sighted students that want to lessen the difficulty level of the game. Nevertheless, students with more gaming habits would rapidly find this interface boring.

The most entertaining interface is probably number 2 (sonar). It is the most provoking of the three and has a great potential to engage students as it enhances the challenge of exploring the game universe. So it would probably be useful for students with frequent gaming habits. However, this interface can provoke fatigue in students if it is used in very long games or the sounds are not carefully chosen.

Interface 3 provides an interesting balance between usability and engagement/entertainment. Regarding usability, if users know the right command that needs to be introduced to trigger an interaction they just need to type in a single sentence. But, which makes the system interesting is that students must apply deduction to find the correct command, and therefore the process is not immediate.

The impact on the game authoring experience differs among interfaces. Interface1 and Interface 3 do not take into account the location of interactive elements on the screen, forcing the author of the game to feed the audio system with descriptions that are automatically spoken using text-to-speech to provide contextualization for the blind user. Interface 2 does not pose this extra burden, but requires the author to specify different multiple sounds for each scene. From a cost perspective entering text is easier than producing additional audio resources. These considerations must be taken into account, given that the goal is to limit the cost needed to make educational games accessible as much as possible.

The following table provides a summary of the characteristics of each interface.

TABLE 1. COMPARISON OF THREE INTERFACES

Interface	Usability	Engagement	Additional Cost
Navigation (1)	↑	↓	=
Sonar (2)	↓	↑	↑
Commands (3)	=	=	=

VII. CONCLUSIONS AND FUTURE WORK

Educational games are gaining momentum very quickly, and they will probably increase their presence in schools and universities in the midterm [3]. However, it is necessary to make an additional effort to ensure the accessibility of games to guarantee they do not create more problems than they solve.

For that purpose we have proposed three interfaces that could be used to improve access to educational games for blind students. The idea is to allow a seamless integration of accessible interfaces in educational games to ensure accessibility is covered.

We have recently conducted a preliminary evaluation with 10 blind users to check the usability of the interfaces generated. The analysis of data collected is among our first lines of future work.

Next steps in this research are to refine these interfaces, use them to develop games and test them with experts in educational game authoring, in order to identify the best practices when designing accessible game interfaces. In addition, it may be possible to combine successful features of different interfaces to produce new interfaces.

Once these interfaces reach a certain level of maturity, it would be necessary to define a system that allows the authors of the game (and/or the users themselves) to setup the interface that is best for them.

Once these actions are accomplished the interfaces will be ready for production stage, and they will be integrated in the public release of the eAdventure platform to allow other game authors and players reuse the work done. Ideally, the integration of accessibility features in the game editors (rather than *ad hoc* modifications for each game) should consequently reduce the cost of introducing accessibility in educational games.

Long term goals of this approach is to make accessible educational games, similar to the ones created in collaboration with CATEDU (Centro Aragonés de Tecnologías para la Educación), without a significant increase in the production costs. These educational games are currently available at http://www.catedu.es/webcatedu/index.php/descargas/e-adventures.

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