Designing Universally Accessible Games

DIMITRIS GRAMMENOS
Institute of Computer Science
and
ANTHONY SAVIDIS and CONSTANTINE STEPHANIDIS
Institute of Computer Science, Hellas (FORTH), and University of Crete

Today, computer games are one of the major sources of entertainment. Computer games are usually far more demanding than typical interactive applications in terms of motor and sensory skills needed for interaction control, due to special-purpose input devices, complicated interaction techniques, and the primary emphasis on visual control and attention. This renders computer games inaccessible to a large percentage of people with disabilities. This article introduces the concept of *universally accessible games*, that is, games proactively designed to optimally fit and adapt to individual gamer characteristics and to be concurrently played among people with diverse abilities, without requiring particular adjustments or modifications. The concept is elaborated and tested through four case studies: a web-based chess game (*UA-Chess*), an action game (*Access Invaders*), a universally inaccessible game (*Game Over*!) used as an interactive educational tool, and an improved version of *Access Invaders* (*Terrestrial Invaders*). For all cases, key design and evaluation findings are discussed, reporting consolidated know-how and experience. Finally, the research challenge of creating multiplayer universally accessible games is further elaborated, proposing the novel concept of *Parallel Game Universes* as a potential solution.

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Authors' addresses: D. Grammenos, Foundation for Research and Technology, Hellas (FORTH), Institute of Computer Science; email: grammenos@ics.forth.gr; A. Savidis and C. Stephanidis, Foundation for Research and Technology, Hellas (FORTH), Institute of Computer Science and Dept. of Computer Science; University of Crete, Greece.

1. INTRODUCTION

Worldwide, at least one person out of ten is disabled due to physical, mental, or sensory impairments (i.e., more than 500 million people), while at least one out of four is adversely affected by disability [United Nations 2004]. Furthermore, aging very often results in limitations in vision, hearing, memory, or motor functions; worldwide there are approximately 600 million persons aged 60 years and over–a number that is estimated will double by the year 2025 and reach two billion by 2050 [World Health Organization 2004].

In the past few years, the accessibility to electronic applications and services by elderly and disabled users has become a topic of great importance at an international level. Based on the fundamental right of all people for equal access to information and services, and equal opportunities for employment and independent living, several governments and political bodies have adopted legislative and policy measures (e.g., Access Board [2000]; European Commission [2002]) towards ensuring (or even enforcing) application software and Web accessibility.

Beyond working and independent living, most people need entertainment, and presently computer games constitute a major part of the entertainment industry. The worldwide computer game industry is vast, and can be compared to the retail sales of books and music, the cinema box office, and VHS/DVD rentals [Screen Digest 2004]. Furthermore, there is currently, a significant trend in employing games for training and learning (known as *game-based learning* [Prensky 2000]) in order to take advantage of the unparalleled motivation and engagement that computer games can offer to learners of all ages. University departments are gradually introducing computer games in their curricula to support alternative learning styles, attract student interest, and reinforce learning objectives (e.g., Giguette [2003]). Games are also promoted as policy education, exploration, and management tools (e.g., the *Serious Games Initiative*[1]).

However, computer games are usually quite demanding in terms of motor, sensor, and mental skills needed for interaction control, and often require mastering inflexible, quite complicated, input devices and techniques. These facts often render games inaccessible to a large percentage of people with disabilities. So far, little attention has been paid to the development of computer games that can be played by all players, independently of their personal characteristics, requirements, or (dis)abilities. Furthermore, concerning human-computer interaction issues, computer games differ fundamentally from all the other types of software applications for which accessibility guidelines and solutions are already becoming widely available.

In the context of this article, the term “accessibility” is not associated to people with physical, sensory, or mental disabilities only (which is typically the case), but it also refers to gamers with *situational disabilities* [Sears et al. 2003]). Those gamers who may not be able to fully experience, or even play, a game due to (a) the environment they operate in (e.g., a person in a noisy

[1]http://www.seriousgames.org/.

environment is situationally deaf; someone using a screen in bright sunlight is situationally blind; (b) the hardware and software they use (e.g., a mobile device with a small screen; an older browser; a different operating system); and (c) their gaming skills and preferences (e.g., a person who experiences difficulty or does not like using ten different keys in order to kick the ball in a football game).

Until now, little attention has been paid to the development of computer games that can be potentially played by all gamers, independently of their individual characteristics, requirements, preferences, and abilities. In particular, there are no computer games that can be concurrently played among able and disabled people, either remotely or sharing the same computer, with the minor exception of a few games that can be played both by visually impaired and sighted players, like *All inPlay* card games[2] and the 3D shooter, *Terraformers.*[3]

This article introduces the concept of *universally accessible games* (UA-Games) as a novel approach to creating games that are proactively designed to be concurrently accessible to people with a wide range of diverse requirements and/or disabilities. In this context, the following research results are presented:

(1) *Unified design for UA-Games*: a structured design method for universally accessible games, based on unified user interface design [Savidis and Stephanidis 2004]. The method follows a step-by-step, top-down approach, starting with a high-level abstract task definition process, leading eventually to the creation of a complex, but well-structured, design space, populated by numerous interweaved physical designs.
(2) Four games that have a two-fold role, acting both as proofs of concept and as case studies:
   - *UA–Chess*: a universally accessible Web–based chess;
   - *Access Invaders*: a universally accessible multiplayer and multiplatform version of *Space Invaders*.
   - *Game Over*!: a universally inaccessible game, meant to be used as an educational tool for disseminating and teaching game accessibility guidelines.
   - *Terrestrial Invaders*: a UA-Game packed with numerous accessibility features which was developed in order to create *Game Over*!
(3) *The concept of a parallel game universes*: which aims to provide a way for creating multiplayer games where people with diverse abilities can play cooperatively, or against each other, while at the same time experiencing the game in an optimally adapted way.

2. BACKGROUND AND RELATED WORK

In contrast to Web accessibility, relatively few efforts up to now have been devoted to game accessibility, which has mainly been a concern organised groups of

[2]http://allinplay.com/games.html.
[3]http://www.terraformers.nu/index.php?option=com_content&task=view&id=34&Itemid=28.

disabled people (e.g., *Audyssey* online gaming magazine[4] and AudioGames.net[5] for the blind, DeafGamers[6] for the deaf), or of companies that produce related products (e.g., GamesForTheBlind.com[7] and BSC GAMES[8] for the blind, Arcess[9] and Brillsoft[10] for the motor-impaired). Currently, the most prominent organized international effort related to game accessibility is the Game Accessibility Special Interest Group[11] of the International Game Developers Association (IGDA), which was formed in 2003 with the aim "to develop methods of making all game genres universally accessible to all, regardless of disability."

More recently, game accessibility began to gain some limited but increasing attention from both the scientific community and the game industry. For example, McCrindle, and Symons [2000] have developed a 3D *Space Invaders* game which combines audio and visual interfaces with force feedback, and Westin [2004] created *Terraformers*, a first-person shooter game that can be played with its visual 3D graphics layer on or off, which is intended to support players with all degrees of visual ability or impairment through a sophisticated layer of sound. Bierre et al. [2005] provided an overview of game accessibility problems faced by people with disabilities and how they tried to overcome them, and discussed the accessibility features included in a handful of commercial games. Atkinson et al. [2006] discussed a number of issues that are key to making first-person shooter games accessible to the blind and vision-impaired, and elaborated on their approach in the context of the AGRIP project.[12]

Gamasutra,[13] which is worldwide the most visited and referenced Web site for the video game industry and professionals, also featured a number of articles related to game accessibility. Bierre [2005] was the first to introduce the topic to this audience. Buscaglia [2006] was concerned with the related legal issues; Zahand [2006] approached the topic from the industry's point of view; and Folmer [2007] suggested the consolidation and use of related interaction design patterns as a means for improving game usability and accessibility.

Beyond the limited published information, the domain of game accessibility is also characterized by a serious lack of related structured methods and software tools. In 2007, the Bartiméus Accessibility Foundation released a beta version of Audio Game Maker,[14] a free application that enables visually impaired people to develop sound-only computer games. Furthermore, in the same year, an open source project entitled "Game Accessibility Suite"[15] was started, aiming

[4]http://www.angelfire.com/music4/duffstuff/audyssey.html.
[5]http://audiogames.net.
[6]http://www.deafgamers.com.
[7]http://gamesfortheblind.com.
[8]http://www.bscgames.com.
[9]http://arcess.com.
[10]http://www.brillsoft.com.
[11]http://www.igda.org/wiki/Game_Accessibility_SIG.
[12]http://www.agrip.org.uk.
[13]Http://gamasutra.com.
[14]http://www.audiogamemaker.com.
[15]http://sourceforge.net/projects/gameaccess.

to create a suite of utilities to make modern Win32 games more accessible (e.g., by adding subtitles, slowing them down, adapting input controllers).

In 2005 and 2006, the Retro Remakes Web site ran game development competitions[16] promoting accessibility in gaming. Also in 2006, donationcoder.com conducted an accessible game-coding contest.[17] In 2007, the KQED Public Broadcasting in San Francisco broadcast a documentary[18] entitled "Video Games - Access for All" and BBC has made some of its children's games switch-accessible.[19]

Currently, there are no related official guidelines, standards, or any world-wide initiatives comparable to W3C-WAI in the domain of game accessibility, and no related governmental or legislative actions. Still, there are two international task forces working towards shaping and consolidating game accessibility guidelines [Ossmann and Miesenberger 2006]. They are

(1) The aforementioned GA-SIG of the IGDA, which in 2004 published a White Paper [IGDA GA-SIG 2004] on game accessibility, including a list of possible approaches for providing accessibility in games. The SIG has also created a "top ten" list of items for game developers to start increasing the accessibility of their games, with minimal effort on their part and without greatly affecting (and perhaps even improving) general gameplay [IGDA GA-SIG 2006].
(2) A group led by the University of Linz and the Norwegian company MediaLT [2004] developed a set of "guidelines for the development of entertaining software for people with multiple learning disabilities." The guidelines published by GA-SIG [MediaLT 2006] aim to create something similar to the W3C/WAI Web Content Accessibility Guidelines.

3. MOTIVATION

From a technical point of view, two main approaches have been adopted to address the issue of computer game accessibility:

(1) Inaccessible games that are made operationally accessible through the use of third-party assistive technologies, such as screen readers, mouse emulators, or special input devices. In practice, there are serious inherent barriers and bottlenecks because not enough (or no) effort is made to ensure compatibility during the development of computer games and assistive technology systems. However, even when some sort of compatibility is achieved, it is typically the result of either customized low-level adaptations (i.e., hacking) or pure coincidence, rather than the outcome of appropriate design considerations.
(2) Accessible games that are developed from scratch, but targeted to people with a specific disability, such as audio-based games for blind people or

[16] http://www.retroremakes.com/wordpress/competitions/.
[17] http://www.donationcoder.com/Contests/agame/intro.html.
[18] http://www.kqed.org/quest/television/view/276.
[19] http://www.bbc.co.uk/cbbc/games/switch.shtml.

single-switch games for people with severe motor impairments of the upper limbs.

Following the first approach, typically a very limited form of accessibility is achieved, coupled with poor interaction quality and usability. This can be attributed to several factors:

- Longer interaction times are required because input and output are not optimized to fit the devices and techniques in use.
- Often, only part of the full available functionality can be made accessible.
- Error-prevention cannot be supported and interaction can be particularly error-prone (e.g., using a mouse emulator to select small areas can be very difficult).
- The approach is limited to reproducing the functionality on offer, instead of redesigning it to suit particular user needs.
- Extensive configuration of physical interaction parameters is required (e.g., mapping between the assistive technologies and the supported devices), in order to achieve usability.
- Impassable implementation barriers can arise (e.g., graphical images cannot be automatically reproduced in a nonvisual form).
- Design conflicts may arise (e.g., having to reproduce drag and drop dialogue technique for blind players).
- Upward compatibility is not offered; when a new version of a game is developed, the accessibility adjustments have to be reimplemented.

Although the second approach is much more promising, it still has two main drawbacks: (a) there is a significant cost associated with the development of high-quality accessible games, while the expected return on investment is rather low, as the target user group represents a limited market; and (b) there is a risk for social exclusion due to the potential for segregation of able and disabled gamers.

In this context, the goal of the work reported in this article is to emphasize a development discipline that would overcome the limitations of existing approaches. In order to achieve this, two new characteristics are required:

> *Games should be inherently accessible to all the potential user groups*, without the need for further adjustments, or third-party assistive software applications.
>
> *The same game should be concurrently accessible and playable*, cooperatively or competitively, to people with diverse abilities.

This new approach is called *universally accessible games* (UA-Games for short). The underlying vision is that through such games people will be able to have fun and compete on an equal basis, while interacting easily and effectively, irrespective of individual characteristics. The potential impact is three-fold:

> makes available an entertaining social experience that would otherwise not exist for a significant percentage of people;

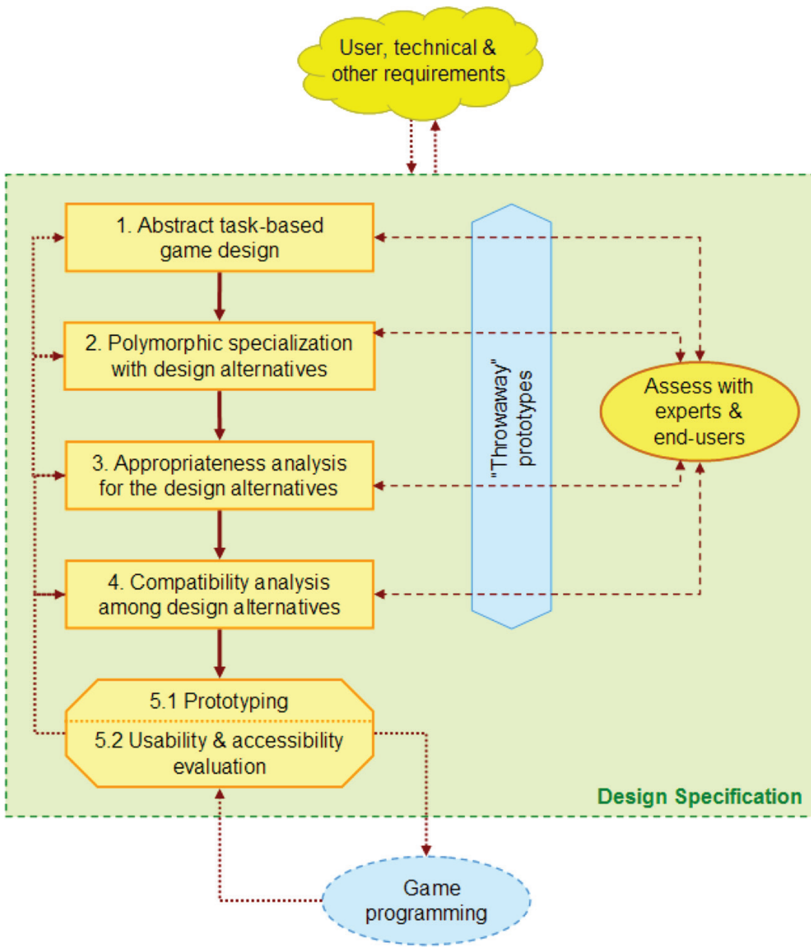

Fig. 1. Applying unified design to the development of universally accessible games.

allows for social interaction among people who may never have interacted with each other otherwise; and

expands the size and composition of the potential market for the computer games industry.

4. DESIGN PROCESS

In order to design UA-Games, a structured design method was followed, based on unified user interface design [Savidis and Stephanidis 2004]. This method reflects a process-oriented discipline emphasizing abstract task definitions with incremental polymorphic physical specialization. Since unified design was originally targeted for the creation of accessible user interfaces, it had to be adapted to cater for the intrinsic characteristics and particular needs of game design. The basic steps in applying unified design to the development of accessible games are summarized in Figure 1. An elaboration of each step of the process is provided in Grammenos et al. [2007].

As shown in Figure 1, it is a highly participatory, user-centered iterative process due to: (a) the direct involvement of several representative end-users (gamers) with diverse characteristics, as well as domain experts (usability, accessibility, gaming, etc.) is promoted throughout the overall lifecycle in order to continuously assess the design outcomes in each step; and (b) it is possible to return to a previous design step in case, for instance, more information is required, some design artifacts have to be revisited, or the design parameters must be specialized further.

In order to evaluate decisions made at a specific step or to weigh alternatives before committing to them, it is often necessary to quickly create small-scale temporary "throwaway" prototypes. These may range from rough hand-made sketches to simple programs. Prototyping is an essential part of the iterative design process because it provides a low cost, tangible means for gathering early and meaningful user feedback, and, at a later stage, may also serve as a common reference point and as a documentation medium for communicating concrete and unambiguous design specifications to game programmers.

At this point, it should be noted that game programmers are also involved in the entire process with a two-fold role: they provide input about technical requirements and restrictions, as well as on the feasibility and cost of alternative design solutions; and they develop and "tweak" the required electronic prototypes.

5. CASE STUDIES

Using the aforementioned unified design method, four computer games were created with a two-fold role: to act as both proofs of concept and as case studies. Two of the games (*UA-Chess* and *Game Over!*) are recipients of awards of distinction, in recognition of their value in providing universal access. All of the games are publicly available at www.ua-games.gr.

The following sections elaborate on the most critical game design decisions and their related design rationales.

6. CASE STUDY 1: UA-CHESS

UA-Chess [Grammenos et al. 2005] is a chess game developed in Action Script 2.0, it runs on any Web browser with a Flash Player plug-in. The game supports the following user categories: users who are sighted; those with low vision; users who are blind; users with hand-motor impairment; and those with mild memory or cognitive impairment.

The two-player mode is facilitated either remotely over the Internet or locally by sharing the same computer, enabling users with different abilities to play together. In the case of local two-player mode, the game's user interface switches automatically from one profile to the other, depending on who the current player is. The game was designed to offer in parallel alternative input and output modalities and interaction methods, reflecting the universal access objective.

All game functions are accessible through the mouse, the keyboard, any kind of binary switch that emulates keystrokes, as well as speech recognition. *UA-Chess* has self-voicing capabilities, provided by a built-in screen reader that

Fig. 2. The visual interface of *UA-Chess*.

offers auditory access to every part of the interface. Since Flash does not offer speech input and output capabilities, the speech application language tags (SALT) technology[20] was employed to support speech recognition and synthesis. SALT is an emergent standard for developing voice-enabled applications for the Web that extends existing markup languages such as HTML and XHTML.

In addition, the game can be sized according to user preference and zoomed in and out at different levels. Alternative interaction techniques (their parameters can be customized) are supported for each device.

UA-Chess was nominated for the final jury decision of the European Design for All Awards[21] by the European Commission in the category AT/Culture, Leisure and Sport, thus becoming officially the first computer game ever that follows the principles of design for all.

The game's visual user interface (Fig. 2.) comprises the following interaction components:

(a) *Menu bar*: provides direct access to all the game functions (e.g., new, load, save, quit), as well as to user profile customization parameters (e.g., input/output preferences).

(b) *The board*: this is the part of the screen where the game takes place. It is composed of an 8-by-8 grid of 64 squares, alternately light and dark. The eight vertical columns of squares are called "files" and are numbered from 1 to 8, while the eight horizontal rows of squares are called "ranks" and are numbered from "A" to "H." A straight line of squares of the same color, touching corner to corner, is called a "diagonal." When a pawn reaches the rank furthest from its starting position, it must be exchanged as part of the same move for a queen, rook, bishop, or knight of the same color (Fig. 3.).

[20]http://www.saltforum.org.
[21]http://www.dfa-at-awards.org.

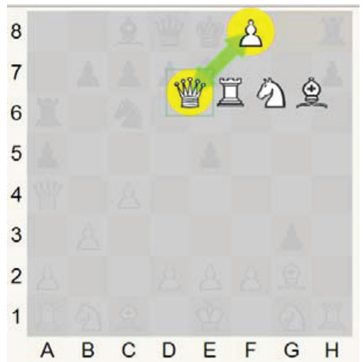

Fig. 3. Pawn promotion dialogue.

Such an exchange of a pawn for another piece is called “promotion.”

(c) *Active player*: The active player is the one who will perform the next move. The related user profile is activated and the user interface is adapted accordingly.

(d) *Moves history list*: Displays all the moves made so far in a game. The “Go back” rolls back to the move before the one selected in the moves list.

(e) *Command feedback line*: Provides visual feedback about speech and text commands that were recognized by the system.

6.1 Design Challenges and Solutions

As *UA-Chess* is the first game of its kind, a number of challenges emerged during its design for which appropriate solutions had to be devised.

6.1.1 *Alternative User Profiles.* At the beginning of interaction, the system should “know” the user’s disabilities to provide adequate means for enabling interaction. A straightforward method to do this is through a profile-selection dialogue. A challenge when designing this dialogue is the paradox that the medium for selecting how the user interface should adapt in order to become accessible, should already be accessible. The only solution to this problem is to embed in this dialogue as many redundant accessibility features as possible. Furthermore, previous experience in the domain of accessibility showed that two types of profiles have to be supported: those that are fixed and those that are user-defined. Fixed profiles are those that can be altered by the user (e.g., while playing a game), but the changes are not saved for future reference. On the contrary, user-defined profiles permanently store user preferences. The utility of fixed profiles is that they can ensure a basic level of accessibility for a specific user group, irrespective of any personal (or accidental) changes made by another player. For example, the profile for a blind user would become inaccessible if speech output were turned off.

6.1.2 *Motor-Impaired User Access through Switch-Based Hierarchical Scanning.* The basic idea of scanning is that a special “marker” (e.g., a colored

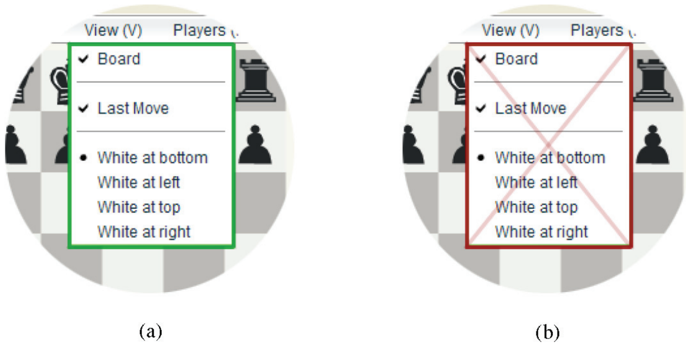

Fig. 4. Scanning: Different states of the input focus.

frame; see Figure 4) indicates the interaction item (e.g., a button, a menu, a piece) that has the input focus [Ntoa et al. 2004]. The user can shift the focus marker to the next/previous interaction object using any kind of switches (e.g., keyboard keys, special switch hardware, or even voice commands). When the focus is over, an object the user wants to interact with (e.g., a chess piece to be selected, a button to be pressed), another switch is used to perform a "selection." Additionally, in cases where the user can use just a single switch, focus movement can be generated automatically by the system at constant time intervals. This variation of the technique is referred to as "automatic scanning," while any other case is generically called "manual scanning" (even if the hands are not actually used at all). In general, there are two types of objects the user can interact with:

Container objects are used to group related objects and increase scanning efficiency. When such an object is selected, scanning is "locked" inside its contents until the user selects to exit. Examples of container objects are the menus, the moves list, and the chessboard, as well as the pieces, since each piece is considered a collection of possible moves.

Simple objects, which cannot contain any other object. When such an object is selected, a corresponding action is performed. Examples of simple objects are buttons, destination moves, and menu and list items.

Depending on the object type, the focus frame can have two different states, which are usually indicated visually with different colors and frame shapes:

Select state (green rectangle, Figure 4 (a)). Upon selection, if the object's type is *simple* then a related action is activated (e.g., a menu item is selected, a button pressed, a piece will move to the selected square). If the object type is *container*, then the scanning focus shifts to its contents (e.g., the pieces on the board, the list of moves, or the contents of a menu).

Exit state (red rectangle with an X, Figure 4 (b)). Only *container objects* can be in this state. Upon user selection, the state changes to "enter" so that the user can either re-enter the object's contents (using "select"), or move on (using "next" or "previous"). Note that the X symbol is used so that color-blind players can differentiate the two states.

6.1.3 *Blind User Access through Nonvisual Navigation.* Nonvisual navigation comprises two parts: input and output. Regarding input, a slightly modified version of hierarchical scanning was utilized. The basic difference is that in this case there are no states. When a container object is selected, the focus does not "lock" in its contents; that is, when the last contained item is scanned, the focus moves to the next interaction object that is at the same level as the container. This technique, as suggested by the results of informal testing of both techniques with end-users, is more suitable and easy to use for blind users than hierarchical scanning, and works similarly to the way they typically use the tab key for accessing Windows applications and Web pages. Additionally, this technique was found very suitable and effective for people playing the game without using a mouse.

Nonvisual output of game-related information can be provided through two modalities: aural (speech and audio) and tactile (Braille display). Since, for the time being, there is no way to control a Braille display through a Web browser, only aural output could be implemented. In order to provide full nonvisual access, a screen reader was integrated into *UA-Chess*, which can "read" both game-related events (e.g., when a piece or a possible move was selected, a piece moved, the active player changed), as well as the currently focused interaction object and its state when using the game's interface elements. With the exception of blind people, the screen reader also helps people with deteriorated vision or dyslexia. In addition to the basic screen-reading functionality, added-value information can be provided orally through a menu or key shortcuts such as the selected piece, the contents of the chessboard, the positions of opponent pieces, and so on.

6.1.4 *Voice Input.* Although speech recognition is now a mainstream technology, it is not widely used, mainly due to its poor results, especially when it is employed by non-native speakers. Due to the high probability of recognition errors, *UA-Chess* provides feedback about what was "heard" by the system. For sighted players, this is done through a "discrete" text message at the bottom left corner of the board. Initially, for blind users, the option of speaking every command that was recognized out loud was considered, but from the very first user test it quickly became apparent that this approach was not appreciated by the users. So, eventually, the compromise solution was on the one hand to provide feedback when a reversible command affecting the game's state was issued (e.g., a piece was selected or moved, a menu option was selected), and on the other hand to ask for explicit user confirmation for irreversible critical actions (e.g., start a new game).

6.1.5 *Access for People with Deteriorated Vision.* As mentioned earlier, people with deteriorated vision can benefit from the screen-reading capabilities of *UA-Chess*. In addition to that, the entire user interface can be resized to any extent. Thus for example, on a 17″ monitor, the chess pieces can become as big as 2×2 cm. Furthermore, there is a zoom feature that can magnify screen elements up to 2400% (i.e., a single chess piece can become as big as the entire

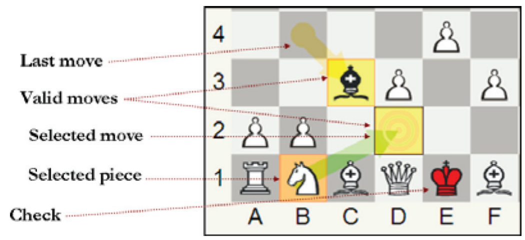

Fig. 5. Available visual cues.

Fig. 6. Alternative board orientation options.

screen). These features are possible because vector graphics which can be resized to any extent without compromising their quality were used.

6.1.6 *Access for People with Mild Memory/Cognitive Impairments.* Several visual cues are available (see Figure 5), such as the last move made, the available valid moves, the currently selected move and piece, and whether the king is in check. Each player can select a different board orientation among the following: white at bottom, white at left, white at top, white at right (Figure 6). A history mechanism is also provided, in the form of a list that displays all the moves made so far in a game. The list uses an adapted shorthand chess notation for the description of moves; but when an item is read it is "translated" into plain language. For example, an entry written as "2... Queen G8 × G5", is read as "move 2, black queen moved from D8 to G5 capturing a pawn." This list is associated with a "go back" button that allows players to roll the game back to a previous state, working as an undo function.

6.1.7 *Supporting "Typical" Windows Users.* Similarly to any "typical" Windows application, the game can also be played using a mouse. In this case, the interaction process is as follows. When the cursor is over a piece that can move, the square on which the piece resides is highlighted in yellow (Figure 7(a)). By clicking on the piece, it becomes selected, and the square is highlighted in orange, while all the squares to which the selected piece can move are highlighted in yellow (Figure 7(b)). When the mouse is over a square to which the piece can move, an orange target appears and a green arrow connects the selected piece with the target square (Figure 7(c)). Clicking on the target square moves the selected piece there.

(a) (b) (c)

Fig. 7. Selecting and moving a piece using the mouse.

6.1.8 *Commandline Input.* Some users were already familiar with online chess servers that used a commandline interface, where, for example, a piece can be selected and moved simply by typing the name of the square where the piece is located and then the name of the target square (e.g., F3F5). So this option was also supported, since it can speed up keyboard-based interaction considerably. Blind players commented that this technique could potentially be useful for them too, but since they were novice chess players they preferred relying on browsing for selecting and moving the pieces.

6.2 Usability Evaluation

A subjective usability evaluation process was carried out with six adult participants (ages 19 to 25): one able-bodied person, two blind persons, and three motor-impaired players (using one, two, and three switches, respectively). The evaluation process was carried out around two basic scenarios, consisting of two rounds per player in an informal competition tournament. The player pairs for each round were chosen randomly. To formally solicit the users' opinion, an adapted version of the IBM Usability Satisfaction Questionnaires [Lewis 1995] was used. The results of the study were very encouraging. More specifically, apart from the very good scores given by the blind and motor impaired users for all metrics (all metrics were below 3, which is considered to be a very good score), it became clear very quickly that the disabled users were enthusiastic that they were given the opportunity to actually play a computer game. Moreover, one very positive element in the overall evaluation process was that the participants did not know their opponents until the game was actually completed. This proved to be another unexpected motivating factor that turned the study into a more interesting "event," something quite typical for computer gameplay sessions.

7. CASE STUDY 2: ACCESS INVADERS

As a first step in investigating the possibility of applying the concept of UA-Games to the demanding field of action games, it was decided to use a simple, popular classic game, namely, *Space Invaders*, originally designed by Toshihiro Nishikado of TAITO Corp. This game is characterized by limited control options

Table I. Overview of *Access Invaders* Content and Logic Adaptation Categories

Category	Example
	Game Content
Speed	Make individual game elements or the gameplay faster or slower.
Quantity	Change the number of aliens and shields.
Size	Make the game elements bigger or smaller.
Layout	Alter the absolute or relative positions of game elements.
Firepower	Supply the aliens or player with faster or slower and more or less powerful weapons or stop them from firing.
Visual complexity	Use backgrounds and graphics with large solid color areas.
Contrast	Use color combinations that provide high contrast.
Sound	Associate spatial feedback to game elements through 3D sound.
	Game Rules
Interaction among game elements	Set which type of aliens can destroy the player's spaceship, and vice versa, and whether the spaceship's bullets can pass through the shields or collide with them.
Analogue vs. digital control	Select whether the aliens and the spaceship move in discrete or continuous positions.
Hints	Make the player's task easier by providing added-value information (e.g., audio radar, visualization of the path of objects, oral descriptions).
Stamina	Provide the player with additional "lives." make the spaceship more resistant to incoming fire and the aliens less so.

and very simple rules, logic, and content. The accessible remake was named *Access Invaders* [Grammenos et al. 2006].

7.1 Profile-Driven Adaptation

This game supports adaptation via *user profiles*. Once a profile is selected, interaction and content adapt to it. Externally, the game looks like a collection of different and accessible versions of the game from which users may choose one. Internally, it is a single application with an abstract skeleton where alternatives are organized according to the concept of runtime *polymorphism* [Savidis and Stephanidis 2004].

7.1.1 *Adapting the User Interface.* The game's interface can be controlled using any, or all, of the following devices: keyboard, mouse, joystick, game pad, and binary switches. The interface includes two basic interaction objects, that is, menu and text entry. Both can be manipulated with any of the aforementioned devices, while the font size and family is configurable. The player's spaceship is controlled through three commands ("move left," "move right," and "fire"), which can be issued using any device. The following user categories are supported: people with hand-motor impairment; blind people and those with low-vision; and people with cognitive impairment.

7.1.2 *Adapting the Game Content and Logic.* A number of categories for adaptation were identified, and are outlined in Table I. Alternative combinations of these adaptations can serve the accessibility needs of each of the target user groups mentioned above. Possible suggestions include:

People with hand-motor impairment: Decreasing the game's pace and the aliens' shooting speed. When the "autofire" option is used, the player's bullets are allowed to pass through the protective shields to reduce the number of controls.

Blind people: 3D sonification of all game elements is required in combination with a decrease in the numbers of aliens and their spread, so that they can be acoustically located in space. For the first levels, the aliens' firing capabilities should be eliminated or reduced so that only a single bomb is active. The player should also be able to shoot a single bullet that reaches its target instantly, since it is very hard to figure out acoustically the exact distance of an alien and the bullet's speed and then devise an appropriate firing strategy (e.g., press "fire" X seconds before the alien is in range). The shields introduce unwanted complexity and confusion, so at least for nonexpert players shields should be avoided. When novice players are in danger or in the right position to shoot an alien ship, discrete movements and auditory feedback improve the playability of the game dramatically.

- *People with deteriorated vision*: A blend of considerably bigger, less complex graphics and fonts, sparsely dispersed in space in high contrast with a solid background, in association with a corresponding decrease of the game speed, is appropriate in most of the cases.

  People with cognitive impairment: Depending on the type and level of disability, as well as on the goal of the game (in this case, besides pure entertainment, computer games are also used as training and rehabilitation tools), accessibility can be achieved through an overall simplification of the game in terms of content, control, speed, and difficulty. Also, visualizing the path of moving objects can aid in understanding the correlation between cause and effect. An important point that should be considered here is the avoidance of blinking and flashing graphics, since at particular rates it can cause photosensitive epileptic seizures in susceptible individuals.

Some screenshots of profiles for *Access Invaders* for different user categories are illustrated in Figure 8.

7.2 Usability Evaluation

Nine adults (ages 19 to 30) participated in the evaluation sessions: three able-bodied, three blind, and three motor-impaired persons. As in *UA-Chess*, an adapted version of the IBM Usability Satisfaction Questionnaires was used. The overall results were very good; but this could also be attributed to the fact that *Access Invaders* is a very simple game to play. After several debriefing sessions with the participants, it came out that the social value of the concept of universally accessible games created a positive attitude, making the players feel less strict and more forgiving. The main complaints came from the blind players, and were related to the speech and sound quality and the lack of an auditory help facility. Almost all the players commented on the difficulty of the game, either because it was too hard or too easy than the players wanted. This problem could have been alleviated by conducting user-profiling sessions prior to the evaluation process and then adapting all difficulty-related game parameters. More detailed evaluation results are available in Grammenos et al. [2006].

Fig. 8. Examples of alternative *Access Invaders'* profiles. From top to bottom, left to right: (a) basic; (b) single-switch; (c) X-Large; (d) nonvisual.

8. CASE STUDY 3: GAME OVER!

In contrast to the aforementioned case studies, *Game Over*! [Grammenos 2008] is not a universally accessible game but a universally *in*accessible one (i.e., a game that can be played by no one). The game is meant to be used as an educational tool for disseminating and teaching game accessibility guidelines by providing game developers a first-hand (frustrating) experience of how it feels to interact with a game that is not accessible because important design rules were not considered or applied during its design.

The research hypothesis underlying the development of *Game Over*! is that a computer game is a suitable means for: (a) increasing game developers' awareness about game accessibility; and (b) teaching them some basic related principles while having fun. Thus, it was decided to develop a "proof of concept" game for testing this hypothesis. As a first step, in order to rapidly test the concept, a simple 2D game was selected that would require reasonable resources.

Game Over! won the People's Choice award at the Arcademy Games Awards[22] in Montreal, Quebec, sponsored by Festival Arcadia. In this event the submitted games were showcased for 22,000 visitors.

[22] http://www.futureplay.org/news.php?id=24.

Fig. 9. *Game Over*! (left); screenshot punch line and guideline displayed at the end of “Level 9. Chill Out!” (right).

8.1 Game Design

The basic high-level requirements were that the game should

(1) be very easy to play, with a well-known goal and mechanics (probably an all-time classic), so that gamers could easily understand the problem and its causes;
(2) break game accessibility rules in a bold and straightforward way;
(3) break one rule at a time in order to simplify the message, making it easier for players to understand what is going wrong and why;
(4) concentrate on major, typical accessibility problems related to the following user groups: blind people, those with deteriorated vision, motor-impaired and deaf people, and also novice players;
(5) provide some advice for solving each problem after exposing the player to it, following the concept of amelioration patterns;
(6) employ humor for lightening up the “educational” process, thus making the game more enjoyable; and
(7) run on as many computer platforms as possible.

A reversal of the stereotypical space invaders scenario was selected as the main game theme. The player assumes the role of an alien hopelessly struggling to protect the universe from the merciless invasion of the terrestrial invaders. This approach serves a two-fold role. On the one hand, it allows most players to know what to expect when playing the game, while, on the other hand, the reversal (which also has a comical effect) predisposes players to feel that there is something radically different about this game.

As expected, the basic gameplay is quite simple (Figure 9) The player controls a flying saucer that is located near the top of the screen (in contrast to the classic *Space Invaders* game), can move left to right and vice versa and throw bombs in order to destroy enemy spaceships, while at the same time trying to avoid incoming fire.

The game comprises 21 levels, each of which violates a fundamental game accessibility guideline. The guidelines were selected by reviewing the related existing collections (e.g., IGDA GA-SIG [2004]; IGDA GA-SIG [2006; MediaLT [2004]; MediaLT [2006]), the authors' experience, and the feasibility of including them in the selected game style. In some cases (e.g., "*provide control over game speed*") there are two levels that address both extreme cases of the same guideline.

The player can play the game from the start, or jump directly to a specific level. The title of the level is given at its beginning, along with some guidance (e.g., the controls that can be used and the player's goal). In order to move from one level to the next one, the player must first lose three lives. Each time that a life is lost, 100 points are subtracted from the player's score. At the end of each level, a well-known quote related to the level's content is recited (i.e., a punch line) providing a humorous note, and the guideline that was violated is displayed (see Figure 9, on the right). At the end of the game, a summary of the level titles and the corresponding (violated) guidelines are presented.

8.2 Usability Evaluation

During both the design and development phases of *Game Over*! several in-house evaluation sessions were conducted with the participation of one experienced software engineer and game developer, a usability expert, a graphic designer, three postgraduate and two undergraduate students of the Computer Science Department of the University of Crete. First, a mock-up of the game illustrating the basic concept was created in MS Powerpoint®. The mock-up was presented to all the evaluators and received positive feedback. Additionally, several comments were collected regarding the potential gameplay, the game presentation, and the sequence of levels. During game development, each time a new level was available it was play-tested by all the evaluators in order to detect bugs, suggest aesthetic improvements, and discover usability and understandability problems.

When *Game Over*! was released on the Web, an electronic form was created for collecting evaluation feedback.[23] The form is made up of two parts, one game-related and the other with demographic questions. The game-related part contains five questions using a five-point scale, accompanied by a text box for noting any additional related comments. Up to now, 49 persons have filled in the feedback form, providing at least their e-mail addresses as a means of identification, while 239 have registered in order to receive further information about *Game Over*! The key survey results follow; more detailed results are available in Grammenos [2008]:

- Seventy-one percent of respondents said that they would definitely recommend playing *Game Over*! to other game designers and developers, and another 14% said that they probably would.
- To the question "How useful do you think that *Game Over*! can be as an educational tool for disseminating, understanding, and consolidating game accessibility guidelines?" 47% answered "very much," 37% said "much," 8% "moderately," 2% "slightly," and 6% "not at all."

[23] http://www.ics.forth.gr/hci/ua-games/game-over/feedback.html

- When asked how much playing *Game Over*! helped them become familiar with game accessibility guidelines and their application, of the people who said that they knew half or fewer of the accessibility guidelines in the game, 38% answered "very much," 33% said "much," and 29% said "moderately," but no one said "slightly" or "not at all."

9. CASE STUDY 4: TERRESTRIAL INVADERS

Terrestrial Invaders is a descendent of *Access Invaders*. Just like its predecessor, the game is packed with several accessibility features that can be switched on and off, both off-line and on-the-fly. *Terrestrial Invaders* is actually a byproduct of the development process of *Game Over*! Through its various accessibility features, *Terrestrial Invaders* is able to address most of the accessibility guidelines that *Game Over*! violates.

9.1 Accessibility features

The accessibility features supported by *Terrestrial Invaders* includes:

- adjustable overall game speed;
- adjustable enemies' speed (they can even be stopped completely);
- adjustable size of all game graphics;
- adjustable size of player bombs;
- separately adjustable FX, music, and speech volume;
- optional specification of the exact number of enemy bullets that can be concurrently active on the screen;
- 2D sound for locating objects on a 2D plane;
- presentation of spatially located captions using text and/or graphics for visualizing all game sounds;
- reading aloud (for the visually impaired) and automatic scanning (for the motor-impaired) of the game menus;
- two high-contrast modes (bright graphics on dark background and the inverse);
- two novel alternative types of audio descriptions (a summary and a more detailed one) that verbalize the relative positions of attacking spaceships in relation to the player and warn of incoming fire;
- the option of using simple shapes (e.g., rectangles, ellipses) to render all graphic elements. This option can be useful to people with severe visual impairment by allowing them to replace detailed graphics made up of big blobs with high-contrast solid colors in combination with 2D sound and audio descriptions. Additionally, it can also be handy for people with some type of cognitive impairment;
- cheats that adjust a game's difficulty: get an extra life, destroy a random enemy, activate the shield;
- controls can also be redefined, but currently this can only be done by editing the respective XML level description files.

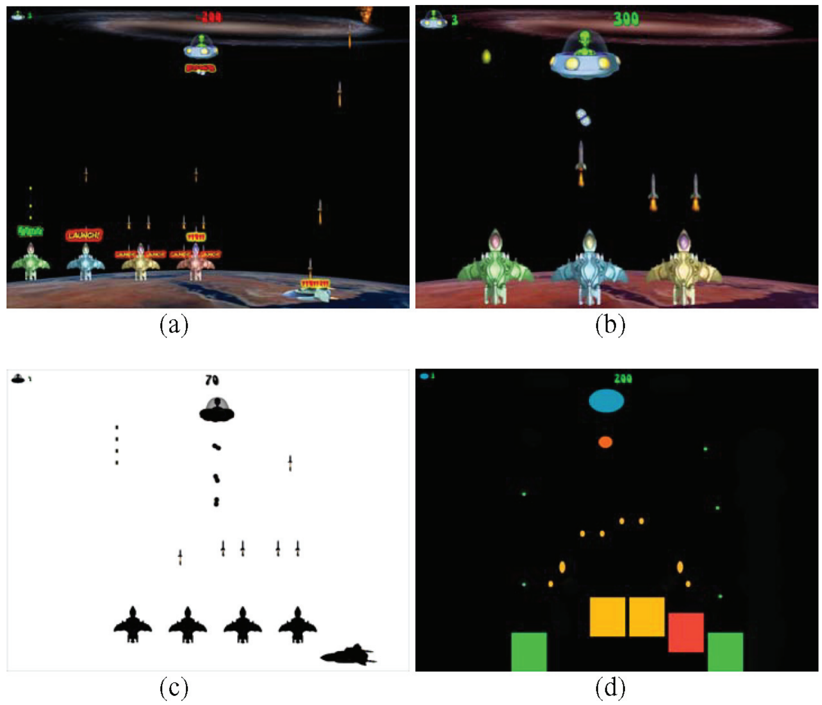

Fig. 10. Example screenshots from adaptations supported by *Terrestrial Invaders*: (a) audio captions; (b) magnification; (c) high contrast; (d) use of simplified graphics.

Some example screenshots of the game are illustrated in Figure 10. The game can be played using diverse alternative controls and interaction techniques such as:

- multiple keyboard keys (or switches);
- a single key (i.e., one-switch game);
- the mouse;
- typing keywords consisting of any number of letters or symbols (e.g., “left” to go left, “right” to go right, etc.).
- blowing into a standard microphone. In this case, the game includes an auto-gain capability that automatically adjusts the microphone input level, so that the game can still be played irrespectively of the microphone’s volume and the environmental noise.

As the case with *Access Invaders*, multiple concurrent players are supported as well as multiple enemy groups. Each player can play against all or specific enemy groups, the characteristics of which (e.g., size, speed, firepower) can be adjusted to fit each player, so that players with diverse abilities can co-operatively play the same game. The game was informally evaluated during its development and an electronic form was created for collecting evaluation feedback from the Web. Currently, the available number of feedback forms is small, and thus there is not enough statistical data for presentation in this article.

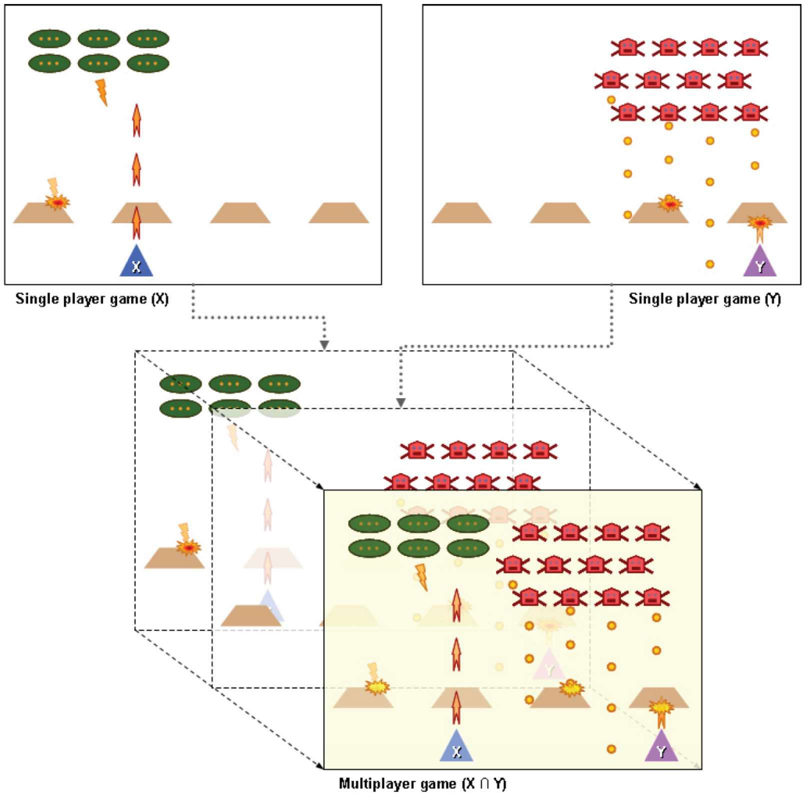

Fig. 11. Example of a multiplayer game following the concept of parallel game universes.

10. THE CONCEPT OF PARALLEL GAME UNIVERSES

How to support multiplayer sessions in which people with diverse (dis)abilities can play a game cooperatively while being fully aware of each other and, at the same time, experiencing the game in an optimally adapted way is an obstacle we encountered while developing the case studies described in the previous sections.

In this context, the concept of parallel game universes (PGUs) was conceived as a solution to this problem [Grammenos 2006]. The suggested approach is to allow each player to play in a different "game universe," and then somehow project each universe to the other(s). A *game universe* is defined as an instance of the game after it has been adapted to best suit the requirements and needs of a particular gamer playing under particular conditions. For example, the alternative profiles of *Access Invaders* or *Terrestrial Invaders* can be considered as different game universes.

As an illustrative example, consider the following situation (Figure 11). Two friends want to play together an invaders-type game. One of them (Player X), due to severe motor-impairment, can use only a single switch. A manageable level of difficulty includes a small group of aliens that move slowly and fire very infrequently, while the player's bullets do not collide with shields. The second, Player (Y), does not have any impairment, so for the game to be challenging enough, he wants to confront numerous fast, fire-blazing aliens. If the two players want to share the same game and the game is adapted to the first player, it will be rather boring for the second, and if adapted to the second player, it will be extremely difficult - if not impossible - for the first. Following the idea of parallel game universes, a possible solution is to merge the two distinct game versions into one. In this new version of the game, two groups of aliens will exist: a big, fast, and powerful one which can destroy and be destroyed only by Player Y, and a small, slow, and quite harmless one that plays only against Player X. One player's bullets will not affect the aliens fighting against the other; Player Y's bullets will collide with the shields, and Player X's will not.

This example is implemented in both *Access Invaders* and *Terrestrial Invaders*, in both there is a game profile that allows for two-player collaboration between a person with and a person without hand-motor impairment.

In the aforementioned example, the process of implementing the common game universe is quite straightforward, since the way that the two distinct universes are rendered are compatible and can easily be merged. A problem arises when two (or more) universes have competing output needs (e.g., the game universe of a person with deteriorated vision where few, large sprites are presented versus one of a fully-sighted player where numerous small sprites exist; or a universe of a blind versus a sighted player where conflicting requirements for aural output are imposed).

In such cases, the concept of parallel game universes can still be implemented, but will require redundant computational resources such as extra sound cards and earphones for providing dedicated sound output to each player, or even multiple computers for projecting different views. Furthermore, a "transition function" is needed for translating the events of one universe to the other in a format that is suitable and meaningful in that universe. It is important to note at this point that the overall objective is not recreating everything that exists or happens in a universe to every other, but just to communicate enough cues so that the players can cooperate in a successful and enjoyable manner. For example, it is desirable for a blind player to know that his/her sighted game partner still has a few or several aliens to destroy in order to complete the level successfully. Furthermore, this transition function may also allow a player to interact with the other universes (e.g., in the previous example, when the blind player has destroyed all the aliens in his/her universe, s/he can lend a helping hand by having some aliens from the sighted player's transferred to his/her universe). Of course, if this happens, these aliens will have to conform to the laws of the blind person's universe (e.g., they will move more slowly, have 3D sound output, and so on). Thus game elements may co-exist concurrently in several universes, but through distinct instantiations that may be radically different. If such a "shared" game element is destroyed in one universe, then all its incarnations in any other universe are destroyed, too.

The concept of parallel game universes does not only apply to cooperative games but to competitive games as well. In such case a key accessibility problem is how to make the game fair. Players' skills vary widely, and hence players' weaknesses need to be compensated for. A plausible solution is to delegate part

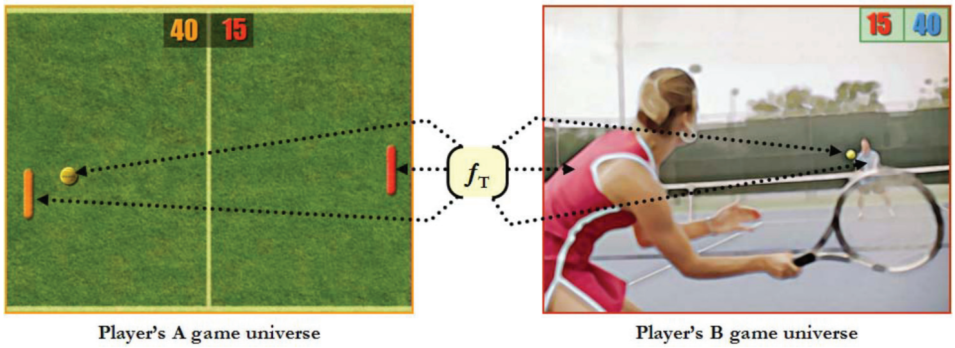

Fig. 12. Example of two players competing in parallel game universes.

of the game control to a "third" party, which can either be another player or the computer, leading to two alternative options:

(1) *Collaborative gaming*. Two (or more) players are acting as one. The control is shared among the players much the way it was in World-War II fighting biplanes, where one person handled navigation while another was responsible for shooting. An example of a hardware device that supports this gaming paradigm is Team Xtreme by Pathways Development Group, Inc. Team Xtreme is a hardware box for N64 in which 1 to 5 switches can be plugged to control any keys of the game controller. This device allows a player with disabilities to team-up with another person, who assists by using a standard game controller.
(2) *AI-supported gaming*. Artificial intelligence (AI) is commonly used in computer games to drive the nonplayer characters (NPCs), such as the monsters in a platform game, the "bad guys" in a fighting game, the opponent brain in a strategy game, the player's sidekicks in a role-playing game, and so on. However, it can also be used to compensate for individual player weaknesses (e.g., novice versus experienced player, single-switch gaming versus full game controller), and work with the player in a synergetic way, similarly to the way another human would in collaborative gaming. Thus, AI-supported gaming has the potential to allow a player to compete on an equal basis against the computer or any other player, irrespective of their individual (dis)abilities.

As a more challenging example, consider a tennis computer game between a blind/motor-impaired (Player A) and a sighted person (Player B); see Figure 12. In the universe of Player A, the game is rendered as a simple 2D game that resembles the game of *Pong* augmented with spatial sound. The player's goal is to pinpoint using hearing the ball's position in the 2D space, and place the bat underneath it using two switches. Through sound, the player can get additional information such as the opponent's position and the current score. In Player's B universe, the game is represented as a 3D realistic tennis simulation seen from a first-person viewpoint. The player controls an athlete using a gamepad and eight buttons. In order to hit the ball, player B has to position the athlete correctly in space and adjust the height and movement of the athlete's arm. The two universes are "synchronized" through a transition function (f_T) which is responsible for translating the ball's and players' 3D positions and speed vectors to 2D, and vice versa.

An interesting, real-life, example of parallel game universes was manifested in August 18, 2000 at the Pelican Hill golf course in Newport Beach, California [Marsden 2001], where people with quadriplegia and paraplegia golfed side-by-side with able-bodied players. The only difference was that the people with disabilities made their shots virtually, using a wheelchair-mounted computer equipped with Madentec's assistive technology and Microsoft's Links golf software with a detailed model of the course, and then followed the path of their virtual ball on the actual course.

11. CONCLUSIONS AND FUTURE WORK

The experience accumulated in the development of the games described in this article shows that designing universally accessible games may be a demanding but still manageable and achievable task that entails doing the following:

(a) Designing for context independence at an abstract level without considering specific interaction modalities, metaphors, techniques or devices and separating the content and the related mechanics from the way that these can be accessed by, and presented to, the user.
(b) Mapping abstract design elements to coherent, usable, and accessible interaction designs that are based on the users' individual characteristics.
(c) Creating user interfaces that can support alternative interaction methods and modalities that can co-exist and co-operate.
(d) Creating user interfaces that are able to adapt to alternative user profiles, that is, sets of preferences, requirements, needs, and contexts of use.
(e) Inclusive and participative design (i.e., considering the broadest possible population during design and with representatives from as many categories as possible participating and providing input to all the development phases).
(f) Design based on incomplete knowledge, as games can target highly diverse audiences.
(g) Open and extensible interaction design so that, later on, it will still be possible to expand the design to cater for more user categories and contexts of use.
(h) Design for atypical user groups, which may have nothing in common with the designer.

An essential characteristic of the UA-Games approach is the (sometimes radical) adaptation of all the key game "ingredients" (e.g., interface, content and mechanics) in order to achieve universal access. During this process, it is likely that the coherence of the gameplay among different player groups may be considerably affected. Of course, any potential related negative or unwanted effects can be avoided, or, at the worst, remedied, since gameplay coherence is a design quality that can be pursued in a way that is orthogonal to the proposed methods for accommodating accessibility and player-oriented adaptation.

Then again, there may be cases where “breaking” gameplay coherence may be the optimal (or the only) way to accomplish universal access. This is due to the main objective of UA-Games: to allow people with diverse characteristics and abilities to play together, cooperating or even competing. For example, following the notion of parallel game universes, different players may not be playing the “very same” game. For instance, in a cooperative game, one player may be having fun fighting against one harmless alien, while another one struggles against a horde of merciless galactic villains. Or, in a competitive game, a player may require extra help from the game’s AI in order to compete. In such cases a key question is whether gameplay coherence actually matters at all. The answer is, of course, highly subjective, but what ultimately matters in our approach is that all these people are given a chance to share the maximum fun and challenge that they can get from a game, without having to compromise, or sacrifice, their personal gaming experience due to their individual differences.

Although most of the examples included in this article refer to 2D games, the concept and principles of UA-Games are not bound to any particular game technology or genre. The design process presented here can aid in the design of any type of accessible game. The accessibility guidelines suggested here, some of which were implemented and adopted by the games in this article, can also be applied to all game genres. For instance, they could be employed (with a different manifestation, naturally) to make 3D action shooters or casual mobile phone games accessible. Additionally, the concept of parallel game universes is entirely technology-independent. In particular, as illustrated in the examples provided here, such games may be shared among multiple participants, each facing a personalized “view” of the game that may be text-based, 2D, 3D, nonvisual (auditory), or even mixed reality (e.g., the Pelican Hill golf game example).

The outcomes of the case studies show that the accessibility and usability of games can be greatly improved through the employment of a user-centered participatory development process that integrates usability evaluation. Concerning formal accessibility and usability evaluation, the main conclusion is that currently available HCI tools are less than adequate or insufficient. The results that they provide are rather questionable and of limited practical value. Nevertheless, they can be very useful as interview triggers by asking participants to justify their judgments. All things considered, the domain of games accessibility and usability evaluation is currently an under-explored, emerging research direction with real - and pressing - needs, which in the near future is expected to gain considerable importance.

The benefits of developing universally accessible games are rather self-evident, since such games cater for the needs and actively support the right of all people for social interaction and play, irrespective of their individual differences, thus providing a stepping stone towards a more inclusive (and fun!) society. Furthermore, this approach has the potential to render universally accessible several “physical” games that in their original form are not concurrently accessible to several groups of people with disabilities.

At this point, it should be made clear that referring to games that are universally accessible means that these games can be played by all people who can potentially play them but are prevented from doing so due to design flaws–and not by all the people in the world. It is obvious that there will always be games that due to their intrinsic characteristics cannot be made accessible to a range of people (e.g., complex strategy games for the cognitively disabled), or when made accessible may have no meaning or interest for those people (e.g., a “find the song title from listening to a melody” game for a deaf person).

In this context, a key research challenge that has not been investigated at all until now is related to developing a new genre of games that inherently have the potential to be universally accessible. In other words, besides devising strategies for making existing types of games accessible, one could also consider all the currently available accessibility methods and attributes, and based on them, create a new type of game in which all (or at least most) of them can be successfully applied and integrated. Furthermore, another related open research issue concerns how technology can act as an intermediary that will permit people with disabilities to perceive an efficient “translation” (i.e., an appropriately adapted version) of very complex artifacts and experiences.

Regarding reaching out, motivating, and educating the game developer community on the subject of game accessibility, the evaluation outcomes of *Game Over*! strongly suggest that computer games and humor constitute a perfect match for tackling this task. In fact, there already are some educators who use *Game Over*! as supporting material for game development, universal design, and accessibility courses. Of course, there is still a lot of room for improvement. In this context, future work comprises two parallel paths. The first is to improve *Game Over*! by: (a) enhancing the existing levels based on the comments received; (b) adding new levels and guidelines; and (c) embedding background information and linking to related online resources. The second path leads to porting the concept to more popular and more interaction-demanding game genres.

In conclusion, the effort towards universally accessible interactive entertainment is very important and beneficial, not only for people with disabilities, but potentially to all people playing games. This effort can have a two-fold impact: on the one hand, it may raise public acceptance and reach of electronic games, and on the other, it can eventually lead to radically reconsider the presently stereotyped target group of “typical gamers” of the worldwide game industry.

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