

Reconfigurable Games - Games that change with the environment

Fabricio N. Buzeto
Department of Computer Science
University of Brasilia

Tiago B. P. e Silva
Department of Industrial Design
University of Brasilia

Carla D. Castanho
Ricardo P. Jacobi
Department of Computer Science
University of Brasilia

Abstract

The purpose of ubiquitous computing lies on making computation invisible to users eyes. Ubiquitous games, on the other hand, try to embed electronic gaming experience into users lives, blending virtual and real components into the play. This type of games represents a challenge for game designers since they need to know which computing resources can be used to create the metaphors that will lead to new experiences. Reconfigurable games are a subset of such games. Their novelty resides in creating games that self-adapt to changes in the real world, creating an ever changing gaming experience. This paper discusses the concept of reconfigurable games. More specifically, we identify the main characteristics of such games and discuss some of the challenges in their development, focusing on the diversity of interaction capabilities available.

Keywords: Ubiquitous Games, Pervasive Games, Reconfigurable Games

Author's Contact:

fabricio@aluno.unb.br
tiagobarros@unb.br
{carlacastanho,rjacobi}@cic.unb.br

1 Introduction

The main purpose behind ubicomp is to make computing as invisible as possible to user eyes. This is achieved by harnessing the potential existent in the computational power spread and embedded in the environment [Weiser 1991]. The purpose of games, on the other hand is to excite players, transporting them to a virtual world where the “magic” happens. By definition, the concepts of ubiquitous computing and games seems to be unlikely to be mixed together [Weiser and Brown 1996]. Even though it did not took long for them to get blended in what would be called *ubigames*.

It is possible to find several definitions for Ubiquitous games. One of the first definitions refers to them as “Ubiquitous Computing Games” [Björk et al. 2002]. At first they were thought as games that would allow players in the real world to share experiences with players in the virtual world. The intent was to begin the creation of a bridge between the traditional way of playing and the new envisioned way. Many other definitions followed such as “Context-Aware Games” [Koskinen and Suomela 2006a], “Pervasive Games” [Tutzschke and Zukunft 2009] and “Trans-Reality Games” [Gutierrez et al. 2011]. Each definition differs slightly from the other, but its central purpose revolves on the idea of mixing virtual elements with real world elements [Guo et al. 2010]. By blending these two a new level of engagement between players and games is reached, blurring the frontier between virtual and real world.

In order to better understand *ubigames* research, some authors [Mcgonigal 2006] distinguish them based on the purpose behind their development. Such classification divides these games into three categories: Colonize Games, Rupture Games and Activation Games. They are defined as follows:

- The purpose of some games is to *colonize* technology through play. They are based on the belief that the fun factor of games can permeate all kinds of technology.
- Others target to cause *rupture* in the way they are played. These games aim to blend itself to the player’s reality while

keeping themselves invisible for those who do not take part in the narrative.

- At last, there are games that *activate* fun on common objects. Such games’ purpose relies on changing the context of the technology embedded in the environment, making it appealing to the act of play.

Games that fall into the “colonization” category use fun as a strong tool of validation for new technologies. Taking advantage of the immersion factor that surrounds games, new technologies can be experienced avoiding the initial strangeness that can affect users. The game “Uncle Roy All Around Us” [Benford et al. 2004] is one example of this approach. It evaluates how trustworthy self-informed location data can be used by a system. This principle is similar to what is done by *FourSquare* [Foursquare 2014a], a location recommendation application that trusts on users information to provide its services.

The proposition brought by the genre known as *ARG* (Alternate Reality Games) is to use the real world as a platform to play the narrative of a game. This is closely related to the kind of “rupture” in the way real and virtual elements are mixed in games. In such games the real world is the game board where a parallel virtual reality takes place. Actions in the game are composed by a mixture of real world (usually location based) and virtual world activities. The idea is to blend player’s everyday situations with the game while still maintaining it invisible to those that are not involved. The interest on this type of game is growing, with many active games currently available. Two remarkable examples are *Ingress* [Google 2014a] and *GeoCaching* [Groundspeak 2014], which have attracted so far almost two million players on their missions.

“Activating” everyday objects for fun purposes is not new. Games like “Hide-and-seek” and “Tag” have been giving new meaning to locations for generations past. However, when such objects are enhanced with computational capabilities, these possibilities become highly increased. This is clearly demonstrated by projects like “Color Flare” [Bekker et al. 2010], where a simple tube has been enhanced with sensors, *LEDs* and speakers. The addition of these capabilities resulted in the creation of more than 30 game variations when freely given to 19 children during an experiment session.

Although many advances have been done exploring new means of user interaction, data collection and innovative ways of providing stimuli, the investigation of new types of game design remains a barely unexplored territory [Stenros et al. 2012]. Since one the main challenges targeted by ubiquitous computing resides on allowing spontaneous device integration in a smart space, such possibility could be used in order to build new types of *ubigames*. They can take advantage of the capabilities present in the environment, enabling new types of interaction, mechanics and game design. We call this new type of *ubigames* as “Reconfigurable Games” since they change themselves according to the configuration of its surroundings. This allows games to harvest the full potential of *ubicomp*, changing the experience according to each situation, providing enhanced fusion of the virtual with the real world. Although these games can be considered also self-adapting games, the changes are not limited to responsiveness or difficulty levelling, but modifying other core elements of the game design during runtime.

This paper is organized as follows. Section 2 presents the basics concepts about how *ubigames* expand the common notion of electronic games. Reconfigurable games are described in Section 3, which discuss how they allow new dimensions to be explored for building new types of *ubigames*. Section 4 explains the challenges involved in building such games and how they have been addressed so far by current platforms. At last, in Section 5 are presented some

final thoughts about this research and its following steps.

2 Ubigames

Ubigames gave birth to some genres of its own. The most notorious among them are the LBGs (Location Based Games) that force players to use their own location as input, which is converted into game actions. Based on this approach, some sub-genres have spawned like “Treasure Hunt”, “Capture the flag” and “Runners”. All of them are directly related to how ubigames increase the boundaries that provides immersion in a game, also known as “The Magic Circle” [Huiizinga 1955]. Such concept is related to the idea that the main goal of players is to feel immersed in the world of the game in order to enjoy it. The means to achieve such state or immersion is placing players in special situations, like a place (your living room) or time (your spare time), that removes the player’s attention from the real world and brings him into the virtual world.

Expanding the edges of the Magic Circle involves three different dimensions [Montola 2005]: Temporal, Social and Spatial. These three dimensions are usually highly restricted to electronic games. Ubigames efforts concentrate in making these restrictions loosen or non-existent as they increase how the game blends with the real world. Complementary to them, a fourth dimension concerning the perception of both system and user can be added as a boundary explored by ubigames as well.

2.1 Spatial Expansion

The “mobility” of a game establishes where it can take place. Traditional electronic games happen on a fixed location, limiting the user to a specific area in order to be able to enter the virtual world of the game. Ubiquitous games, on the other hand, are expected to be allowed to take place wherever the user wants. A high degree of mobility is not only desired, but a goal for increasing the embeddedness level of the game into the real world. Such games can expect physical spot to be related to virtual places as well. Although some ubigames can take place in fixed or indoor spaces, they can also explore these restrictions by giving new meaning to where in those spaces the user is located. Location Based Games are the best known genre of games that takes this expansion in consideration.

2.2 Temporal Expansion

Regarding “temporality” of a game (when it can be played), the more flexible the better. This way, games that impose boundaries to when or how long a game can be played are considered less ubiquitous. On the other hand, games that allow players to interact with the game world whenever is desired, and in an open ended game session, are considered more ubiquitous. Such games are closer to how everyday life occurs, where there is no limitations to when you can interact or until when it can be played. ARGs explore this expansion in order to allow users to choose when to be active or inactive in the game world. While playing, user’s influence is direct, but when “offline”, the game keeps on with the interaction of other players.

2.3 Social Expansion

A game is not necessarily an individual experience, the player may be also interested in how to “socialize” through the game. Individual experiences are very limited, when considering the degree of immersion that the game provides. This can be enhanced presenting a reality where multiple players can interact with each other. Such interaction can be limited to competitiveness or cooperation (individual or team based). But games that allow a community experience achieve greater proximity between the virtual world and real world. That is why community experience is more suitable for ubiquitous games. Again ARGs allow high levels of social interaction, letting players to expand the game story through game mechanics, forums and even meetings and gatherings.

2.4 Perception Expansion

The way a game is played is determined by its “perception” of the world around it. Such perception is composed not only by how the user perceives the game but also how the game perceives the user. Interactions that occur through traditional peripherals like keyboards, mice and controllers are perceived as limited. It is expected from ubiquitous games to explore less conventional and more natural means of interaction. Among these are included voice commands, visual and gesture recognition, biometric data, interactive objects and localization. Regarding on how the system can interact with the user, screens and private sounds are to be avoided as its primary means. On the other hand, ambient projections, augmented reality, tactile feedback and ambient sound effects present more intuitive ways of delivering information to the user.

Nevertheless, just creating new means of perception does not expand the limit of choices that the player has for interacting with the system. With so many different types of devices available and a wide variety of inputs and outputs, the ability to choose which are best suited for each situation is still a challenge. Such capability is what would allow this dimension to be expanded beyond its current state.

3 Reconfigurable Games

The arcades were one of the first platforms for electronic games. Since then a vast range of devices has been developed to attend the needs of this market. As an example it can be cited eight generations of video game consoles, PCs and a various mobile devices. With such a variety of options, game producers have to choose which will be targeted by their game designers and developers. The other option would be to re-develop those titles in order to fit into the multitude of current platforms. Such games, that are available in multiple devices, are named “Cross-Platform” or “Multi-Platform”.

Although challenging and many times requiring some adaptation, during the conversion between platforms core elements of the game remains unchanged. This way, transporting a game title from one platform to another does not make the best use of the interaction and design capabilities that each one of them can offer. Considering the wide range of devices that are available in a smart space, the potential interaction may become substantial. The idea behind a “Reconfigurable Game” is to reorganize itself in order to explore alternative immersion experiences based on the potential interactions offered by existing devices.

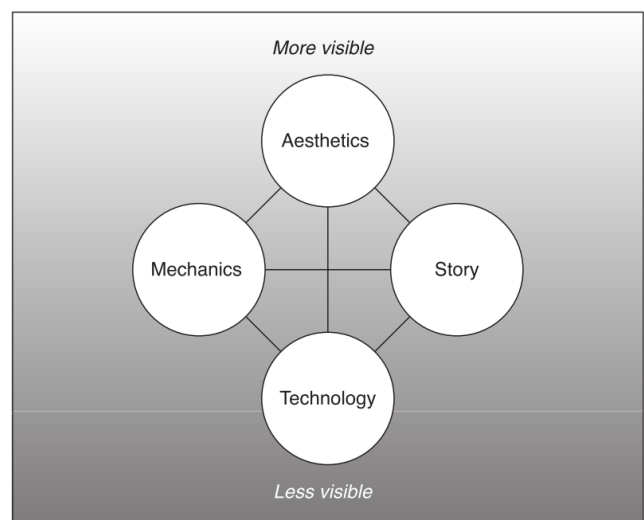


Figure 1: Elemental Tetrad of games. [Schell 2008]

In order to adapt, the first step is to know which elements compose the game and how they can interfere with the game design. As shown in Figure 1, a game can be seen as a composition of four elements [Schell 2008]:

- **Aesthetics** define how the player perceives and interact with the game. It includes all resources that stimulates the senses during the game like graphics, sound effects and others.
- **Mechanics** is composed by the rules that operate the game. It defines which objects can interact with the user and how interaction occurs. Establishing the reactions that can be triggered by each interaction performed by the player is also part of the mechanics.
- **Story** establishes the sequence of facts that are represented through the game. It is responsible for creating the feeling of immersion with the player through the sense of causality and progression.
- **Technology** is responsible for connecting all other elements so they can react to the physical world, allowing the game to happen.

Multi-platform games only adapt to the technology, keeping other tetrad elements unaltered. Although, some cross-platform games involves the adaptation of graphical elements to best fit the platform capabilities, this does not alter the kind of stimuli offered, thus maintaining the aesthetics unchanged. Finally, these changes happens while the game is built, not being changing after packaging and delivery. On the other hand, a Reconfigurable Game aims on adapting the game to explore the available computing capabilities, being defined as follows:

A Reconfigurable Game changes the behaviours defined on its Mechanics, Aesthetics, Story or Technology in real time, according to the resources and devices available in the environment.

A Reconfigurable Game aims on combining available devices and adapting other elements to the changes in the technology. This is achieved in real time, allowing for a different game experience according to each distinct environment configuration. This makes each space a different opportunity to enjoy the same game. It allows games to behave differently on each environment, changing not only when finding new devices or users but also other game instances. As an example of such kind of “Spontaneous Game” we present the concept game “uClue”, that follows this idea.

3.1 uClue

The Game *uClue* is a variation of the traditional detective board game called *Clue*¹. The purpose of the game is to solve a mysterious murder that happened in the mansion where the players are located. The story begins with each player receiving a call from Miss Scarlet². As soon as all players arrive a blackout occurs. When the lights come back on, Miss Scarlet is found dead. Now each one of the players must discover where, how and who committed the crime.

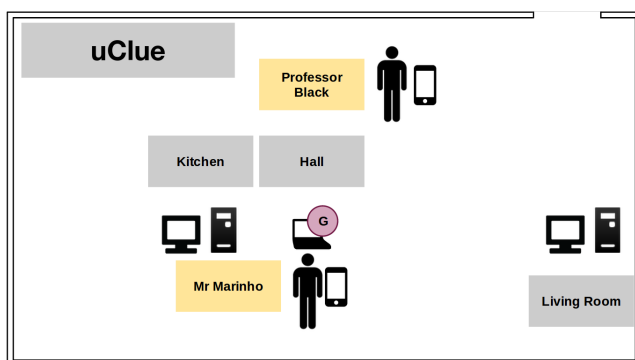


Figure 2: Example of a *uClue* environment and its metaphors for the devices in it.

¹Also known as Cluedo, it was designed by Anthony E. Pratt and published by Waddingtons, Parker Brothers and Hasbro

²The caller name changes for each game session. This makes each of them a different mystery to be solved.

The game watches for devices in the environment and uses them as elements of the game. PCs and Laptops represent rooms of the mansion while portable devices are the detective characters used by players (Figure 2). A sound is played in a room where an event has just taken place, players must go to that room in order to collect clues that will help in their investigation. If any device is able to provide information about heart-rate frequency, for example, it could be used to increase or decrease the frequency of events, regulating the tension among players. The first detective to guess correctly where the crime took place, who is the murderer and with which weapon the crime was committed, wins the game.

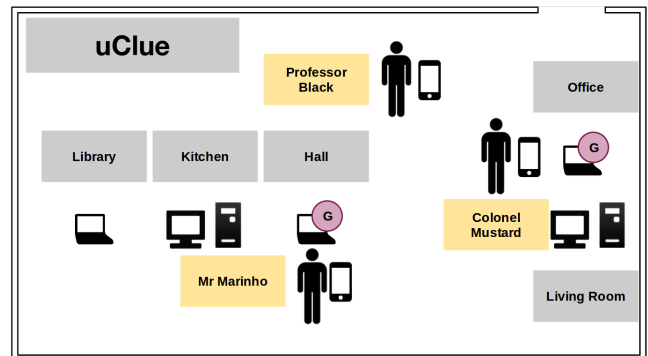


Figure 3: Example of a *uClue* environment with the arrival of new devices and multiple game instances.

As new devices appear in the environment, the game adapts unlocking new rooms and characters to the plot (Figure 3). If another game instance is found, a multiple murder mystery takes place, where characters from each mansion can collaborate or obstruct each other. This self-adaptation of the game makes each environment configuration a different and new game experience changing both complexity and difficulty of the mystery to be solved.

3.2 Levels of Reconfigurability

The definition of a Reconfigurable Game, states that any component of the “Elemental Tetrad” must change according to the configuration of the environment. Since all the elements of the tetrad are related, and those at the bottom are far from the user’s eyes, the impact of adapting an element like Technology is less relevant to the game design when compared to changing the Story. Based on this idea, these games can be divided in three levels of reconfigurability according to which components are influenced by the changes detected in the smart space.

3.2.1 Level 1 - Incorporating devices

As new devices become available in the environment, these games adapt the current game session incorporating them but leaving the mechanics, aesthetics and story unchanged. Such games can aggregate players by promoting the compatibility of their devices and inputs into the game. Examples of this strategy can be found at “Super Sync Sports” [Google 2014b] and “uMoleHunt” [Buzeto et al. 2013] games which consider each new device as a new controller to the game. The game “Battlefield 4TM” is a known multi-player FPS³ but it also contains a playable mode named “Commander” [Electronic-Arts 2014], shown in Figure 4. This mode allows one of the members of each team to play a RTS⁴ which helps him to devise strategies for their team. This mode is available for players on the console along with the FPS mode. If a player has a tablet available, it can be used as a specific controller for the “Commander” mode, since a touch-screen interface is better fitted for the task.

The game does not need to limit itself only on incorporating input devices but also including output devices. This can be found on 4th generation consoles where streaming technologies allow players to enjoy the game on a portable device while away from the TV set.

³First Player Shooter

⁴Real Time Strategy



Figure 4: *Battlefield 4™: Commander* being played on a tablet device. [Electronic-Arts 2014]

For example, the “Remote Play” allows games like “God of War” (Figure 5) and “Bionic Commando” to be played on a PS-Vita device just as it is done on TV with the *Play Station 4*. This context adaptation, from the TV to the portable device, happens in real time.

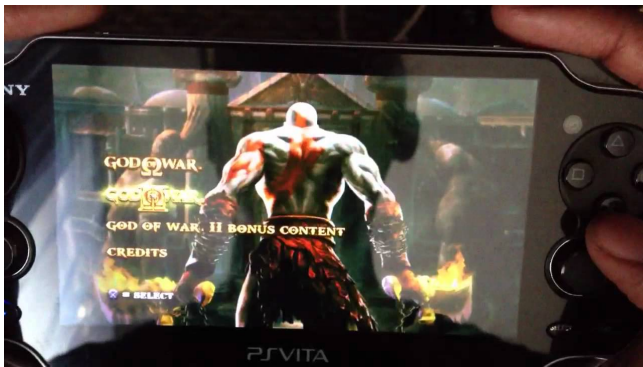


Figure 5: *God of War* being played on a PS-Vita device using the Remote Play streaming technology. [SCE 2013]

3.2.2 Level 2 - Adapt to devices

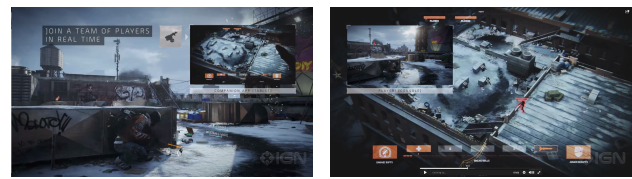
These games focuses on adapting the aesthetics and mechanics elements of a game in accordance to specific capabilities of each device, keeping the story unchanged. For example, new devices can be used as complementary information sources. The game “Forza Horizon” (Figure 6) is a good example of this case, using the “Xbox SmartGlass” technology it have access to any available *tablet* or *smart-phone* available in the room. These devices are then turned into a *GPS*⁵ containing data about races that are happening inside the game world.



Figure 6: *GPS* complementary data being displayed on the game *Forza Horizon* using the *Xbox SmartGlass* support. [Playground-Games and Turn-10 2012]

⁵Global Positioning System navigation device also known as personal navigation assistant

Such games can also take advantage of the diverse input capabilities of each device enabling new game mechanics accordingly. This way each hardware configuration creates a distinct experience. The game “The Division” exemplifies this situation. It allows players using the console “Xbox One” to have a *FPS* experience of the story (Figure 7(a)) while those on a *tablet* have access to a *RTS* game mode (Figure 7(b)) only.



(a) *FPS* console only mode.

(b) *RTS* tablet only mode.

Figure 7: Two distinct game experiences presented by the game *The Division*. [Ubisoft-Massive et al. 2014]

3.2.3 Level 3 - Complement the experience

These games do not limit themselves to adapt the mechanics or aesthetics of the game but also the narrative of the game, creating new stories. These stories can only be experienced with different configuration of devices. This way, each device enables unique possibilities of plot development that complement the game’s main plot.

The Game “Dead Rising 3” (Figure 8) allows players to connect their smart-phones with the game. From this moment forward the device is considered as the main character’s own phone and is used as such by other characters inside the game. The phone is not only used to display extra information but also as a mean of communication with the player character. This way, the player can be contacted and summoned to take part on new chapters of the story, only available through this type of interaction.



Figure 8: Various types of interaction available through the player’s smart-phone connected to the game *Dead Rising 3* using the *Xbox SmartGlass* support. [Capcom 2014]

The complementarity can go beyond the boundaries of a single game as in the case of “Grand Theft Auto: iFruit” [Rockstar 2014] and “Pokemon: Dream World” [Nintendo 2014]. These games allow each device to present different mechanics and story from the main game title, specific for each targeted device. Even though, the results on these games are reflected on the main game and vice versa. On “Pokemon: Dream World” (Figure 9) the main game takes place on the portable console “Nintendo DS” and it has a mechanic composed of battles between captured monsters known as *pokemons* that are controlled by their trainer, the player. When away from the portable device, the player can use its PC browser to engage in casual-games that increase the *pokemon* level of friendship with its trainer. The result of these casual-games can be new items or the improvement of the monsters’ attributes, when the player is back to the main game. Another source of interaction is the “Pokewalker”, a pedometer device that allows the trainer to carry one of its *pokemon* with himself for a walk. The more the player walks, the stronger it gets. It also allows to interact with monsters and other players on other *pokewalkers* nearby.



(a) At the *Nintendo DS* mobile console.

(b) At the computer browser.



(c) At the *Pokewalker* device.

Figure 9: Three distinct game experiences for the game *Pokemon Black and White* at the *Pokemon Dream World* platform. [GameFreak 2011]

4 Challenges of Reconfigurable Games

Reconfigurable Games as ubigames themselves are demanding not only to game developers but also to game designers. One of the main concerns that game designers have is regarding which capabilities are available to be used in the game. On the other hand, game developers needs are related to how to bind together different devices and game instances in real-time.

For game designers, the main question surrounds the *interaction capabilities* that are available to be explored. For example, in a Level-1 game you can use both a smartphone accelerometer or a depth camera to receive gesture commands. This knowledge impacts in how the corresponding metaphor of these inputs will be built in the game. More than that, having a full view from the range of interaction capabilities and how to acquire them allow the game to take advantage of them and achieve its goal of bringing the game world closer to the real world.

Knowing the targeted devices and types of interaction help game developers to establish which platforms and communication networks must be supported. Also, knowing which information is needed by the game allows to define the software architecture and interfaces these devices must satisfy in order to be integrated at runtime. These needs overlap with the challenges that ubicomp itself tries to overcome [da Costa et al. 2008] among which can be highlighted:

- **Heterogeneity:** Integrating a diversity of devices means supporting different types of hardware, software platform and networks.
- **Mobility:** Not only devices can come and go from the environment unexpectedly but also the game device can move to different environments, and the game session along with it.
- **Spontaneous Interoperation:** New devices can become available during runtime bringing with them new capabilities to the smart space.
- **Transparent User Interaction:** User interaction must be blended with the real world.
- **Context Awareness:** The game must be sensitive to changes in its surroundings.
- **Context Management:** Not only aware of what is going on in

the smart space, the game must change its behaviour accordingly.

- **Invisibility:** Devices must not be the center of attention and must try to blend themselves with the environment.

Here is presented a set of interaction capabilities and examples of devices and methods for acquiring them. It is based on the study of a wide range of ubigames crossing many different genres from both Academia and Commercial publishers as presented on Table 1. It is also discussed the current state of ubigames platforms and its deficiencies for attending reconfigurable games.

4.1 Interaction Capabilities

Knowing which means are available for the system to perceive its surroundings and interact with it is essential for game designers. It allows them to create correlations that the game world will have with the real world which in turn is what gives an improved sense of immersion. For example, knowing that the user opened a box in the real world can be translated as opening of a treasure chest in the game world. Based on the analysis of the set of games shown in Table 1 a list of thirteen types of inputs and outputs has been elaborated. Along with them are depicted examples of how they can be used in ubigames and which devices and methodologies could be used to access them in the environment.

- **User:** User information is as important as it is complex. The GUMO Ontology [Heckmann et al. 2005] alone lists almost 1.000 concepts related to this type of information. Among those the identity of the user places itself as one of the most important when building a game. Sensing the presence and knowing who are the people somewhere can be achieved by many means. From simple solutions like relating a person to the presence of a personal device (like a smart phone) or a wireless tag (like RFID) to more complex methods such as face recognition or audio fingerprinting.
- **Controller:** A controller is the most traditional gaming device that exists. From the Atari Joystick to the PS4™DualShock®4, it consists of a group of movement levers, buttons and triggers. Aside from controllers themselves, the same function can be achieved through other means like mice, keyboards, motion sensors and smart phone accelerators and touch screens.
- **Object:** Just like knowing which users are somewhere is important, the same applies to objects in general. Knowing which objects are present allows the game to incorporate them to the game narrative and increase the level of relatedness with the current environment. The most common used way of acquiring this information is through wireless tags (like RFID and NFC) but other means such as image recognition and QR codes can also be used.
- **Object Interaction:** Besides knowing that an object exists in the environment, being able to interact with them is what really aggregates value to their presence. This allows to go beyond the simple logic of checking if a treasure chest is in the right place, to knowing that it was properly opened. This type of interaction can be sensed through various means: buttons can indicate direct intentions; magnetic sensors can indicate bending and opening; accelerometers can indicate movement and gesture.
- **Relative Position:** Positioning is very important to create games where players movement is an integral part of them. Relative position can indicate where something or someone is in comparison to a controlled spot. This is interesting for games where the controlled position and the range of actuation is related to the game, like a room or a building. As an example the Kinect sensor provides three-dimensional position and tracking information according to where the device is placed. Triangulation using radio signals is another method for acquiring the same data but using more relative spots.
- **Absolute Position:** Absolute positioning requires knowing the coordinates of an object or person in global scale. This

Augmented-TCG [Sakamoto et al. 2013]	Speed Biking [Koskinen and Suomela 2006a]
MuseUs [Coenen et al. 2013]	Magic Mushroom Race [Koskinen and Suomela 2006a]
Outbreak: Safety First [Gutierrez et al. 2012]	Cannon Game [Koskinen and Suomela 2006a]
U-Theater - Smash the Beehive [Hwang et al. 2012]	Save the Princess! [Mottola et al. 2006]
Swan Boat [Hwang et al. 2012]	Tycoon [Oppermann et al. 2006]
SwordFight [Zhang et al. 2012]	Hitchers [Drozd et al. 2006]
Hoodies and Barrels [Arroyo et al. 2011]	ShootBall [Sugano et al. 2007]
Adaptative Target Shooting Bike Game [Silva and El Saddik 2011]	Cron [Linner et al. 2005]
Outdoor Pico Safari [Gutierrez et al. 2011]	Uncle Roy All Around You [Benford et al. 2004]
Campus Mysteris [Gutierrez et al. 2011]	Can you see me now? [Benford et al. 2003]
Treasure Hunt NFC [Garrido et al. 2010]	FantasyA [Prada et al. 2003]
iCat (Chess) [Castellano et al. 2009]	Smart Playing Cards [RÄumer and Domnitcheva 2002]
Sanningen om Marika [Waern and Denward 2009]	Touch-Space [Cheok et al. 2002]
King of Location [Tutzschke and Zukunft 2009]	Movement Smash Game [Headon and Curwen 2002]
Battle Bots [Bekker et al. 2010]	Movement Quake H[Headon and Curwen 2002]
FeedBall [Bekker et al. 2010]	AR-Quake [Thomas et al. 2000]
MultiModal Mixer [Bekker et al. 2010]	Nevermind [Mollusk 2014]
UbiBall [Easterly and Blachnitzky 2009]	Ingress [Google 2014a]
Moving Monk [Akribopoulos et al. 2008]	Geo Caching [Groundspeak 2014]
Assassin Apprentice [Akribopoulos et al. 2008]	Pokemon Dream World [Nintendo 2014]
Day of the Figurine (DoF) [Flintham et al. 2007]	LandLord Game [Quip 2014]
Love City [Oppermann et al. 2007]	Game of Cones [Foursquare 2014b]
Professor Tanda [Greenhalgh et al. 2007]	Banco Imobiliário [Estrela 2014]
Mobi Missions [Greenhalgh et al. 2007]	Super Sync Sport [Google 2014b]
IFloorQuest [Grønæk et al. 2007]	World Wide Maze [Google 2014c]
Drink Some Beer [Koskinen and Suomela 2006a]	Grand Theft Auto V: iFruit [Rockstar 2014]
Snow War [Koskinen and Suomela 2006a]	Battlefield 4™: Commander [Electronic-Arts 2014]
Hunters [Koskinen and Suomela 2006a]	Zombies Run [Alderman 2014]
Treasure Hunt [Koskinen and Suomela 2006a]	Run an Empire [Barker and Hill 2014]
Pre-Emptive Strike [Koskinen and Suomela 2006a]	Moff [Moff 2014]

Table 1: List of games considered for this study.

is useful for games that take place on open environments or in metropolitan areas, requiring little or no set up regarding its boundaries. The most common mean of retrieving this data is using GPS devices, but can also be determined based on a relative position where the global position of controlled spots are previously known.

- **Storage:** Storing information on devices allows games to distribute its logic and create spontaneous interactions without using a central server. For example, a game can allow users to leave their mark on objects by storing their identification. This way other players that interact with that object can know who was there before them.
- **Audio Input:** Microphones can provide both individual or public audio information for the game. Individually they can be used for commands, or messaging, but when brought together they can be used to connect environments based on the noise at its surroundings.
- **Audio Output:** Public speakers and head phones provide group and individual audio stimuli for players. Sound effects project feedback about actions about what is happening in the game. Background music can be used to give a sense of immersion or emotion about to the environment related to the virtual world it represents.
- **Image Input:** Real world images, usually captured using cameras, can be used to integrate what the users sees to what the gaming world perceives. Examples can range from a simple texture application to scenery and object collection on a treasure hunting.
- **Video Output:** Video is the most common game stimuli used in electronic games. Screens can be found on monitors, LPDs⁶, cellphones or embedded in other objects. Visual feedback can be very useful for the game, but must be used with care to not require all the players attention reducing the level of engagement with the environment.

- **Text Input:** Textual commands represents a more general type of input for a player's character in the game. Although this type of interaction is usually gathered using keyboards, speak recognition and gestures can also be applied. This type of open interaction demands more intelligent responses from games, but also transmits an increased feeling of reality.
- **Text Output:** Most games trust on visual outputs, but textual inputs are easier to achieve technically (like using low cost LED displays). This limitation can be exploited in the game where small textual feedback can be attached to real world objects.

This list is not exhaustive, for example biometric information like heart-rate, *GSR*⁷ or emotions are not defined. Although they are considered of high interest for ubigames, they also are highly specific. As such, this list is open for extension and must be updated with new types accordingly. Even though, it provides game designers with an wide view of which capabilities can be used when building a game in this context. With this information is possible to better choose which metaphors to be explored when designing the correlations between the real and virtual world.

4.2 Platforms

Bringing the game design into reality is a task for game developers and, as discussed before, involves a set of challenges that are common among other games. That is why the application of known architectures, frameworks and middlewares comes in handy in order to reduce the effort spent during development. As these platforms overcome the those challenges, developers are allowed to focus most of their attention on the game logic. Many platforms have been developed focusing on ubigames but they still lack the characteristics required for reconfigurable games.

The *MUPE* (Multi-User Publishing Environment) [Koskinen and Suomela 2006b] is a middleware focused on context aware games. Its environment is composed by a set of contextual information providers that are used as inputs to the game. These inputs are

⁶Large Public Displays

⁷Galvanic Skin Response

interpreted by a central server where the game rules are executed. The visual output is received by users on JME⁸ enabled phones. The server produces XML messages representing the graphic interface output, which are then interpreted by the framework embedded in the phones. These features allow game developers to focus on the game logic, leaving the middleware to handle input and output tasks. Although the middleware supports some limited heterogeneity on the client devices, it does not allow new inputs or outputs to be integrated during runtime, restraining mobility and lacking of spontaneous interoperation. As for types, MUPE provides seven different kinds of inputs that can be used on games, which include: Absolute Position, Relative Position, Object (identification), Heart-rate and Bicycle RPM⁹.

The PSD (Player Space Director) [Hwang et al. 2012] is a platform focused on allowing availability of heterogeneous devices for ubigames. Its architecture places the game rules at a central server which can inject contextual queries on devices encountered in the smart space. These devices are responsible for connecting to various sensors and actuators and evaluating registered queries based on the information acquired. This allows both spontaneous integration and mobility to take place on games developed on the platform, but it leaves sensors and actuators interfaces to be defined by developers. This way, the integration code and interface for new providers must be built by the game developer, reducing the chances of code reuse.

The fAARS (for Augmented Alternate Reality Services) [Gutierrez et al. 2012] is an evolution of the fAR-PLAY (for Augmented Reality Play) [Gutierrez et al. 2011] framework. It focuses on Augmented and Alternate reality games, specifically on the treasure-hunt genre. These games invite the player to search the environment for objects and places in order to achieve his/her goals and progress through the narrative. The only information used by the game is the players' location, which is acquired using QR Code markers or GPS data. The game logic runs on a server that exchanges HTTP requests with cellphones used by players as their game interface. This allows new devices to freely come and go from the game session. It also limits the interaction possibilities between the game and users since it relies on limited client interfaces available on the devices. The focus on a single type of input is very restrictive on the possibilities of real world integration that the game could take advantage of using the platform.

One common characteristic of these platforms is that all game logic are executed on a central server. This is a common architecture design for multi-player games, since it is easier to have a central location responsible for decision making, avoiding much communication between different nodes. Even on cloud based distributed games, a single node is responsible for defining the outcome of the game session. This strategy is not well suited for spontaneous games, where the surroundings are integrated dynamically into the game. This includes other game sessions running on different devices. Also, all platforms impose specialized APIs for handling outputs, which do not allow game developers to benefit of well established gaming frameworks like Visual and Physics Engines.

5 Conclusion

The electronic gaming industry has been on a continuous search for new ways and dimensions that can be applied on its titles. Ubigames portray themselves as one of the means of extending existing gaming boundaries further into peoples lives and into the real world, opening a wide range of possibilities. This paper presented reconfigurable ubigames as one of these possibilities where the pervasiveness of computing capabilities in the environment can be better explored in order to achieve immersion and integration between the real world and virtual world.

The three levels of reconfigurability of a game, based on the Elemental Tetrad, present a basis for creating new games. The examples presented help game designers in the quest for innovative solutions where reconfiguration can range from small to integral part

of the game concept. Additionally, all levels were exemplified by commercial titles, demonstrating an existing and growing interest to exploit this kind of interaction.

The identification of a set of inputs and outputs typically used in ubigames, along with samples of its use and acquisition methods, intends to help game designers as well. It can make it simpler to envision how such elements can be used in the games and choose those that are adequate to fulfil the metaphors that the virtual world imposes in the real world.

At last, the discussion on current platforms shows that they are not fully fit yet for building reconfigurable games. As future work, the intention is to take such discussion into account and use it in order to build a platform that satisfies these requisites. Using such platform will make it easier to empirically explore how reconfigurable games can be used to achieve new boundaries regarding player interaction and game design.

Acknowledgements

The authors gratefully acknowledge the financial support to Fabricio Buzeto from CAPES (*Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*) for the period of this research.

References

- AKRIBOPOULOS, O., BOUSIS, D., EFSTATHIOU, D., KOUT-SOURIDIS, H., LOGARAS, M., LOUKAS, A., NAFAS, A., OIKONOMOU, G., THIREOU, I., VASSILAKIS, N., KOKKINOS, P., MYLONAS, G., AND CHATZIGIANNAKIS, I. 2008. A software platform for developing multi-player pervasive games using small programmable object technologies. In *Mobile Ad Hoc and Sensor Systems, 2008. MASS 2008. 5th IEEE International Conference on*, 544–546.
- ALDERMAN, N., 2014. *Zombies run*. Available at <https://www.zombiesrungame.com/> (accessed at 01/03/2014).
- ARROYO, I., ZUALKERNAN, I. A., AND WOOLF, B. P. 2011. Hoodies and barrels: Using a hide-and-seek ubiquitous game to teach mathematics. *Advanced Learning Technologies, IEEE International Conference on 0*, 295–299.
- BARKER, B., AND HILL, S., 2014. *Run an empire*. Available at <http://runanempire.com/> (accessed at 01/03/2014).
- BEKKER, T., STURM, J., AND EGGEN, B. 2010. Designing playful interactions for social interaction and physical play. *Personal and Ubiquitous Computing 14*, 5, 385–396.
- BENFORD, S., ANASTASI, R., FLINTHAM, M., GREENHALGH, C., TANDAVANITJ, N., ADAMS, M., AND ROW-FARR, J. 2003. Coping with uncertainty in a location-based game. *Pervasive Computing, IEEE 2*, 3 (July), 34–41.
- BENFORD, S., SEAGER, W., FLINTHAM, M., ANASTASI, R., ROWLAND, D., HUMBLE, J., STANTON, D., BOWERS, J., TANDAVANITJ, N., ADAMS, M., FARR, J., OLDROYD, A., AND SUTTON, J. 2004. The error of our ways: The experience of self-reported position in a location-based game. In *UbiComp 2004: Ubiquitous Computing*, N. Davies, E. Mynatt, and I. Siiio, Eds., vol. 3205 of *Lecture Notes in Computer Science*. Springer Berlin / Heidelberg, 70–87.
- BJÖRK, S., HOLOPAINEN, J., LJUNGSTRAND, P., AND ÅKESSON, K. P. 2002. Designing ubiquitous computing games - a report from a workshop exploring ubiquitous computing entertainment. *Personal Ubiquitous Comput.* 6, 5-6, 443–458.
- BUZETO, F., CAPRETZ, M., CASTANHO, C., AND JACOBI, R. 2013. uos: A resource rerouting middleware for ubiquitous games. In *Ubiquitous Intelligence and Computing, 2013 IEEE 10th International Conference on and 10th International Conference on Autonomic and Trusted Computing (UIC/ATC)*, 88–95.
- CAPCOM, V., 2014. *Dead rising 3*.

⁸Java Micro Edition

⁹Rotations per Minute

- CASTELLANO, G., LEITE, I., PEREIRA, A., MARTINHO, C., PAIVA, A., AND MCOWAN, P. 2009. It's all in the game: Towards an affect sensitive and context aware game companion. In *Affective Computing and Intelligent Interaction and Workshops, 2009. AII 2009. 3rd International Conference on*, 1–8.
- CHEOK, A. D., YANG, X., YING, Z. Z., BILLINGHURST, M., AND KATO, H. 2002. Touch-space: Mixed reality game space based on ubiquitous, tangible, and social computing. *Personal Ubiquitous Comput.* 6, 5-6 (Jan.), 430–442.
- COENEN, T., MOSTMANS, L., AND NAESSENS, K. 2013. Museums: Case study of a pervasive cultural heritage serious game. *J. Comput. Cult. Herit.* 6, 2 (May), 8:1–8:19.
- DA COSTA, C. A., YAMIN, A. C., AND GEYER, C. F. R. 2008. Toward a general software infrastructure for ubiquitous computing. *IEEE Pervasive Computing* 7, 1, 64–73.
- DROZD, A., BENFORD, S., TANDAVANITJ, N., WRIGHT, M., AND CHAMBERLAIN, A. 2006. Hitchers: Designing for cellular positioning. In *UbiComp 2006: Ubiquitous Computing*, P. Dourish and A. Friday, Eds., vol. 4206 of *Lecture Notes in Computer Science*. Springer Berlin / Heidelberg, 279–296.
- EASTERLY, D., AND BLACHNITZKY, A. 2009. Ubiball: A ubiquitous computing game for children. In *Proceedings of the 13th International MindTrek Conference: Everyday Life in the Ubiquitous Era*, ACM, New York, NY, USA, MindTrek '09, 41–44.
- ELETRONIC-ARTS, 2014. Battelfield 4™: Commander. Available at https://play.google.com/store/apps/details?id=com.ea.game.warsawcommander_row (accessed at 01/03/2014).
- ESTRELA, 2014. Banco imobiliário. Available at <https://play.google.com/store/apps/details?id=br.com.pontomobi.estreladigital.bancoimobiliario> (accessed at 01/03/2014).
- FLINTHAM, M., SMITH, K., BENFORD, S., CAPRA, M., GREEN, J., GREENHALGH, C., WRIGHT, M., ADAMS, M., TANDAVANITJ, N., FARR, J. R., ET AL. 2007. *Day of the figurines: A slow narrative-driven game for mobile phones using text messaging*. na.
- FOURSQUARE, 2014. Foursquare. Available at <https://www.foursquare.com/> (accessed at 18/06/2014).
- FOURSQUARE, 2014. The game of cones. Available at <http://gameofcones.foursquare.com/> (accessed at 01/03/2014).
- GAME-FREAK, 2011. Pokemon black and white.
- GARRIDO, P., MIRAZ, G., RUIZ, I., AND GOMEZ-NIETO, M. 2010. Near field communication in the development of ubiquitous games. In *Internet Technology and Secured Transactions (ICITST), 2010 International Conference for*, 1–7.
- GOOGLE, 2014. Ingress. Available at <http://www.ingress.com/> (accessed at 01/03/2014).
- GOOGLE, 2014. Super sync sports. Available at <http://chrome.com/supersyncsports/> (accessed at 01/03/2014).
- GOOGLE, 2014. World wide maze. Available at <http://chrome.com/maze/> (accessed at 01/03/2014).
- GREENHALGH, C., BENFORD, S., DROZD, A., FLINTHAM, M., HAMPSHIRE, A., OPPERMAN, L., SMITH, K., AND VON TYCOWICZ, C. 2007. Addressing mobile phone diversity in ubi-comp experience development. In *UbiComp 2007: Ubiquitous Computing*, J. Krumm, G. Abowd, A. Seneviratne, and T. Strang, Eds., vol. 4717 of *Lecture Notes in Computer Science*. Springer Berlin / Heidelberg, 447–464.
- GRØNBÆK, K., IVERSEN, O. S., KORTBEK, K. J., NIELSEN, K. R., AND AAGAARD, L. 2007. Igamefloor: A platform for co-located collaborative games. In *Proceedings of the International Conference on Advances in Computer Entertainment Technology*, ACM, New York, NY, USA, ACE '07, 64–71.
- GROUNDSPeAK, 2014. Geocaching. Available at <https://www.geocaching.com/> (accessed at 18/06/2014).
- GUO, H., TRTTEBERG, H., WANG, A., AND ZHU, M. 2010. Temps: A conceptual framework for pervasive and social games. In *Digital Game and Intelligent Toy Enhanced Learning (DIGITEL), 2010 Third IEEE International Conference on*, 31–37.
- GUTIERREZ, L., NIKOLAIDIS, I., STROULIA, E., GOUGLAS, S., ROCKWELL, G., BOEHLER, P., CARBONARO, M., AND KING, S. 2011. far-play: A framework to develop augmented/alternate reality games. In *IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM Workshops), 2011*, 531–536.
- GUTIERREZ, L., STROULIA, E., AND NIKOLAIDIS, I. 2012. faars: A platform for location-aware trans-reality games. In *Entertainment Computing - ICEC 2012*, M. Herrlich, R. Malaka, and M. Masuch, Eds., vol. 7522 of *Lecture Notes in Computer Science*. Springer Berlin Heidelberg, 185–192.
- HEADON, R., AND CURWEN, R. 2002. Movement awareness for ubiquitous game control. *Personal and Ubiquitous Computing* 6, 407–415.
- HECKMANN, D., SCHWARTZ, T., BRANDHERM, B., SCHMITZ, M., AND VON WILAMOWITZ-MOELLENDORFF, M. 2005. Gumo – the general user model ontology. In *User Modeling 2005*, L. Ardisson, P. Brna, and A. Mitrovic, Eds., vol. 3538 of *Lecture Notes in Computer Science*. Springer Berlin Heidelberg, 428–432.
- HUIZINGA, J. 1955. *Homo Ludens: A Study of the Play-element in Culture*. Beacon paperbacks ; 15 : Sociology. Beacon Press.
- HWANG, I., LEE, Y., PARK, T., AND SONG, J. 2012. Toward a mobile platform for pervasive games. In *Proceedings of the first ACM international workshop on Mobile gaming*, ACM, New York, NY, USA, MobileGames '12, 19–24.
- KOSKINEN, K., AND SUOMELA, R. 2006. Rapid prototyping of context-aware games. In *Intelligent Environments, 2006. IE 06. 2nd IET International Conference on*, vol. 1, 135–142.
- KOSKINEN, K., AND SUOMELA, R. 2006. Rapid prototyping of context-aware games. In *Intelligent Environments, 2006. IE 06. 2nd IET International Conference on*, vol. 1, 135–142.
- LINNER, D., KIRSCH, F., RADUSCH, I., AND STEGLICH, S. 2005. Context-aware multimedia provisioning for pervasive games. In *Multimedia, Seventh IEEE International Symposium on*, 9 pp.
- MCGONIGAL, J. E. 2006. *This might be a game: ubiquitous play and performance at the turn of the twenty-first century*. PhD thesis, University of California.
- MOFF, 2014. Moff. Available at <http://www.moff.mobi/> (accessed at 01/03/2014).
- MOLLUSK, F., 2014. Nevermind. Available at <http://www.nevermindgame.com/> (accessed at 18/06/2014).
- MONTOLA, M. 2005. Exploring the edge of the magic circle: Defining pervasive games. In *CD-ROM Proceedings of Digital Arts and Culture. Copenhagen*, 1–3.
- MOTTOLA, L., MURPHY, A. L., AND PICCO, G. P. 2006. Pervasive games in a mote-enabled virtual world using tuple space middleware. In *Proceedings of 5th ACM SIGCOMM workshop on Network and system support for games*, ACM, New York, NY, USA, NetGames '06.
- NINTENDO, 2014. Pokemon dream world. Available at <http://www.pokemon-gl.com/> (accessed at 14/01/2014).
- OPPERMAN, L., BROLL, G., CAPRA, M., AND BENFORD, S. 2006. Extending authoring tools for location-aware applications with an infrastructure visualization layer. In *UbiComp 2006*:

- Ubiquitous Computing*, P. Dourish and A. Friday, Eds., vol. 4206 of *Lecture Notes in Computer Science*. Springer Berlin / Heidelberg, 52–68.
- OPPERMANN, L., JACOBS, R., WATKINS, M., SHACKFORD, R., TYCOWICZ, C. V., WRIGHT, M., CAPRA, M., GREENHALGH, C., AND BENFORD, S. 2007. Love city: a text-driven, location-based mobile phone game played between 3 cities. *Pervasive Games-Concepts & Technologies*.
- PLAYGROUND-GAMES, AND TURN-10, S., 2012. Forza horizon.
- PRADA, R., VALA, M., PAIVA, A., HOOK, K., AND BULLOCK, A. 2003. Fantasia ? the duel of emotions. In *Intelligent Virtual Agents*, T. Rist, R. Aylett, D. Ballin, and J. Rickel, Eds., vol. 2792 of *Lecture Notes in Computer Science*. Springer Berlin / Heidelberg, 62–66.
- QUIP, 2014. The landlord game. Available at <https://www.foursquare.com/> (accessed at 18/06/2014).
- ROCKSTAR, 2014. Grand theft auto: ifruit. Available at <https://play.google.com/store/apps/details?id=com.rockstargames.ifruit> (accessed at 01/03/2014).
- RÄÜMER, K., AND DOMNITCHEVA, S. 2002. Smart playing cards: A ubiquitous computing game. *Personal and Ubiquitous Computing* 6, 371–377.
- SAKAMOTO, M., ALEXANDROVA, T., AND NAKAJIMA, T. 2013. Augmenting remote trading card play with virtual characters used in animation and game stories-towards persuasive and ambient transmedia storytelling. In *ACHI 2013, The Sixth International Conference on Advances in Computer-Human Interactions*, 168–177.
- SCE, S. M. S., 2013. God of war collection.
- SHELL, J. 2008. *The Art of Game Design: A book of lenses*. Morgan Kaufmann. Taylor & Francis.
- SILVA, J., AND EL SADDIK, A. 2011. An adaptive game-based exercising framework. In *Virtual Environments Human-Computer Interfaces and Measurement Systems (VECIMS), 2011 IEEE International Conference on*, 1–6.
- STENROS, J., WAERN, A., AND MONTOLA, M. 2012. Studying the elusive experience in pervasive games. *Simul. Gaming* 43, 3 (June), 339–355.
- SUGANO, Y., MOCHIZUKI, Y., USUI, T., AND OKUDE, N. 2007. Shootball: The ball sport using dynamic goals. In *Proceedings of the International Conference on Advances in Computer Entertainment Technology*, ACM, New York, NY, USA, ACE '07, 262–263.
- THOMAS, B., CLOSE, B., DONOGHUE, J., SQUIRES, J., DE BONDI, P., MORRIS, M., AND PIEKARSKI, W. 2000. Arquake: an outdoor/indoor augmented reality first person application. In *Wearable Computers, The Fourth International Symposium on*, 139–146.
- TUTZSCHKE, J., AND ZUKUNFT, O. 2009. Frap: a framework for pervasive games. In *Proceedings of the 1st ACM SIGCHI symposium on Engineering interactive computing systems*, ACM, New York, NY, USA, EICS '09, 133–142.
- UBISOFT-MASSIVE, UBISOFT-REFLECTIONS, AND UBISOFT-RED-STORM, 2014. Tom clancy's the division.
- WAERN, A., AND DENWARD, M. 2009. On the edge of reality: Reality fiction in Åsanningen om marikaÅŽ. *Breaking New Ground: Innovation in Games, Play, Practice and Theory. Proceedings of DiGRA*.
- WEISER, M., AND BROWN, J. S., 1996. The coming age of calm technology.
- WEISER, M. 1991. The computer for the 21st century. *Scientific American*.
- ZHANG, Z., CHU, D., CHEN, X., AND MOSCIBRODA, T. 2012. Swordfight: Exploring phone-to-phone motion games. *Pervasive Computing, IEEE* 11, 4 (Oct), 8–12.