What is going on with ubicomp games

Fabricio N. Buzeto Ana H. O. R. Castillo Carla D. Castanho Ricardo P. Jacobi
Department of Computer Science
University of Brasilia

Abstract

Games are a kind of application that stimulate the absorption of new technologies and forms of interaction by the user. During game sessions, players tend to be more receptive to changes, diminishing the strangeness of some innovative technologies. On the other hand, ubicomp started as a vision of a world where the computer vanishes in the environment, helping and interacting with users in a unnoticeable way. The combination of games and ubicomp is relatively new. The ludic and engaging aspects of games can be used to investigate ubicomp technologies on one side and, on the other, it is highly probable that ubiquitous games will play an important role in game market in the future. This article presents a study of ubiquitous games developed over the last decade. By analyzing them, it is possible to extract some common characteristics for comparison purposes. Therefore, this work search to highlights traits considered relevant for game design, providing guidelines for future research of ubigames.

Keywords:: Pervasive Gaming, Ubiquitous Computing Games, Context Awareness

Author's Contact:

fabricio@intacto.com.br
anaozaki@unb.br
{carlacastanho,rjacobi}@cic.unb.br

1 Introduction

Twenty years ago, when ubicomp concepts were first coined in Xerox labs [Weiser 1991], there was a huge gap between its goals and the available technology. Since then, the continuous evolution of devices, integrated circuits and communications reduced (but not eliminated) this gap. Today, laptops, smart-phones and a wide variety of connected gadgets are not far from users everyday lives. However, devices interfaces are still based on traditional computer I/O, which requires much of the attention of its users, playing a central role in their tasks. This goes on the opposite direction of what is envisioned by ubiquitous computing, which aims to minimize human machine interaction, supporting user tasks in a pervasive way [Weiser 1993]. The creation of smart spaces is essential to achieve this goal. These environments intend to pro-actively support its users into accomplishing tasks. While doing so, the system captures as much of information as necessary in order to infer the human intention and make decisions accordingly [Krumm 2009]. The concept of peripheral attention, where systems operate in background, interacting minimally with users, is very important to the development of ubiquitous applications. This requirement also relies on strongly connected environments, where devices are integrated and cooperate to learn users preferences. Smart space design involves places such as homes [Jansen 2005], workplaces [Garlan 2002], and others. Touch screens and voice controlled gadgets became very common over the last five years. However, despite research results to make user interfaces more natural, traditional devices such as keyboards, mouses and screens continue to be the most common form of human-machine interaction. Alternatives like HUD (Head-up Display) [Pope 2006], whose concept is more than a century old, have very slow adoption among users. Games are used in ubiquitous computing for shortening the path to the adoption of new concepts and technologies. The idea is to take advantage of the fact that players have a greater engagement with games than on a "serious application". This is an effect of the playful aspects of the task involved. Other characteristic of games is that players want to be challenged, which contributes to the acceptance of new concepts, preventing the rejection of ideas that initially could be considered strange. This advantage has been explored by other pervasive applications, such as FourSquare, GetGlue and AccidentBucket [Law et al. 2011], where a game layer is placed over the application in order to achieve better spontaneity in user interaction. Ten years ago [Bjrk et al. 2002] the research involving Ubiquitous Games (ubigames) was at its beginnings. Then the concern was mostly focused on how to make a better use of context information, with special focus on location information, which would provide means to target the user. Back then, the integration among virtual and real elements was sparse, giving little sense to the pervasive dimension of ubigames. This work presents the evolution of the such games since then. It is also presented a set of traits shared among projects. By analyzing them, it is possible to observe correlations between their main characteristics and point out guidelines for future research.

2 Motivation

Computer games are a part of modern society with applications not only to amusement but also to health care, education and many others. The game industry has also been a benchmark for detecting trends to the whole computer industry. Ranging from GPU architecture to interaction devices, games have been used as early testbeds for many *state of the art* concepts. Following the same idea, ubicomp has taken advantage of the application of games as means to validate different concepts for building smart spaces. Besides the growth of mobile platforms, the scenario ten years ago lacked of a greater use of the computing capabilities available today. This leads research [Bjrk et al. 2002] to try to foresee how would be the reality a decade after (nowadays). The portrayed scene pointed to a greater use of games as means to blend society and applications while taking advantage of sensors an actuators. Through the observation of research development over this period, it is possible to capture which concepts are shared among projects. Such concepts serve as a knowledge base for upcoming strategies, helping the characterization of possible solutions. It is also possible to extract which fields have been most fruitful and which ones have been neglected, showing trends for new research.

3 Dimensions of ubigames

A game involves the creation of a limited reality [Crawford 1984] even if it tries to emulate the real world. While creating these environments it is needed to think about different elements of game design. Such elements include the game play and rules that must be respected, the story that will bring immersion and the interface that will be used [Rollings and Morris 2003]. Observing the scenario of ubigames, it is possible to extract some common elements among them. These dimensions correspond to the rules (Environment), game play (Player Flexibility) and the interface (Context Data and User Interaction) with players.

3.1 Environment

The kind of environment exploited by games are very intertwined with the game motivation (story) and its mechanics. It can be classified into two groups: *Outdoor* games which takes place on open spaces (such as parks or cities), and *Indoor* games that are played on closed spaces (such as rooms or houses). Indoor games allow better control over the information gathered from players since space limitations tend to simplify the interaction and also minimizes the interference from external entities. Such environments also enable the exploitation of a greater range of sensors and other computing capabilities during game sessions. Since the space is reduced there are limitations on the number of players and often demands better accuracy of location sensors. On the other hand, open space games

exploits more interaction with real world components (since control over the environment is reduced). Such games tend to rely strongly on location and flexible relations among players.

3.2 Player Flexibility

Usually, ubigames are expected to allow a large number of players, making use of the available resources around them. Although most of them are designed this way, the flexibility regarding number of player vary from game to game and can be classified into four types:

- *Single-player* games limit their interaction to one player at a time. Most of those games focus on exploiting new kinds of sensors and interfaces, as the single player approach simplifies the analysis.
- *Team-play* games divide players into different groups interacting at the same time. They are characterized by a limited number of players on each team, which is related to the game mechanics.
- *Multi-player* games involve a large range of players simultaneously with more flexibility on the rules and how they can be organized.
- *Collaborative* games involve very flexible rules, which allows the game to adapt itself to the number of players available in each game session. Such games are more common in outdoor places, involving metropolitan areas.

The classification of team-play and multi-player games are closely related, though, there is distinction between both of them regarding the number of players. This allows to categorize games with strict rules (such as card games) as team-play while more flexible ones (like a FPS game) are classified as multi-player. The collaborative games have a strong relation with MMGs (Massively Multi-player Games), although the collaborative trait of ubigames focus on a larger range of players.

3.3 Context Data

The information gathered from the environment is responsible for enhancing the experience of the game. Such information can be obtained from sensors or by observing user actions during the game. The dynamics of the game is fundamental to establish how each type of data will be employed. Among the kinds of context information, some are highlighted:

- The user *identity* is a very common information, since it is crucial for the game behaviour. The way it is obtained varies from less interactive methods, such face and voice recognition, to classic ones (e.g., logins and id tokens).
- Knowing the player *location* allows the system to take actions and to send information directly to the user. This also allows a spatial interaction, which brings the feeling of an immersive experience.
- Some games exploits *biometric* data like heart-rate and skin conductivity obtained from sensors. This kind of data is mostly used by applications involving physical activities.
- Data about user *feelings* can be collected using both direct and indirect techniques to influence the game behavior. This kind of data allows a greater proximity with users.

3.4 User Interaction

The way players interact in ubigames are very important to characterize them. Most of the games still use mouse, keyboard and monitors from traditional *PCs* as interfaces. This type of interaction is very limited when compared to exploiting the various elements present in the environment. Also it has less proximity with reality during game sessions. When mobility is required, the most used devices are *cellphones* and *tablets*. Public data, provided with *LPDs (Large Public Displays)* and *audio systems*, while still stationary represent a good approach for ensuring information mobility. Some games require *specific devices* in order to interact with players. Such devices varies from simple sensors and actuators to more specialized ones such as dolls and tokens. They can provide a closer relation between the user and the space during game sessions, since objects from the real world are reflected in the system. Other devices used for this purpose are HUDs (Head-up Display) and projectors.

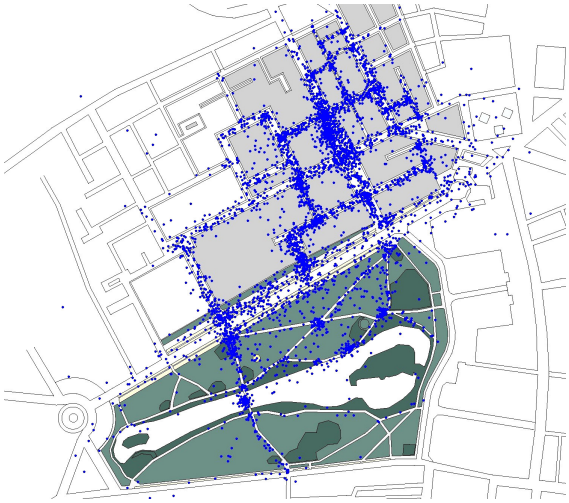

Figure 1: *Uncle Roy All Around You game play area. [Benford et al. 2004]*

4 Ubiquitous Games

This section presents various ubigames encountered during research. Some of them are briefly described to exemplify the characteristics discussed in Section 3.

4.1 Uncle Roy All Around You

This game [Benford et al. 2004] focus on the chase of the fictitious *Uncle Roy* through town. It exploits self informed location information provided by players through the use of *PDAs*. On the screen is possible to view a map version of the game area, which included a park and a city square (Figure 1), where the current position should be informed. The player is able to navigate the map to see all available locations and point where is its current location. For each interaction the user receives a new set of clues that will help on its task. They included not only informations provided by the game itself but also by collaborative online players. The purpose of the game was to test how users would interact with self informed location and the tests showed that a very reasonable accuracy can be achieved using this method. Other behaviors were also noted like the fact that users would inform they position prior or after being on the informed spot. This happened in order to overcome limitations by the system itself like the delay to gather information or the lack of information history. The map browsing also proved that users tend to not vary the map area far from its current location, in search for nearby spots, which can be used to also locate the user position. The use of location as context information allows the game to relate virtual elements (clues) to real world ones (places) and the *PDAs* are a well chosen interface to provide mobility through the game. As a open space game the collaborative mechanics provided a very flexible set or rules which allowed tests reaching almost 300 players.

4.2 Hoodies and Barrels

Focused on a educational game for mixing exercise and learning for kids, H&B [Arroyo et al. 2011] put math elements into the traditional *Tag Game*. For playing children must wear electronic augmented jackets, named Hoodies, and interact with special tokens named Barrels. This concept of weaving electronics into common world objects is called as *E-Textiles*. The game can take place into two different formats. In a more controlled one, the teacher estab-

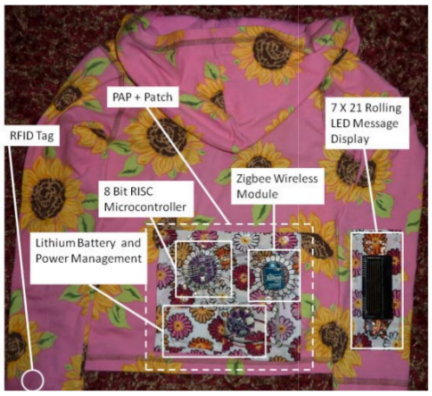

Figure 2: *Hoodie used by kids and its components. [Arroyo et al. 2011]*

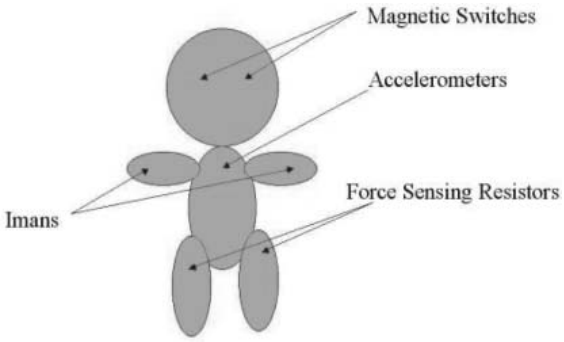

Figure 3: *Sentoy doll sensors. [Prada et al. 2003]*

lishes a set of challenges and boundaries that must be respected for each student. These challenges involves math problems regarding distances and sizes about players and barrels. Players must respect those rules while trying to solve problems. The second format is played very similar to a "hide and seek" game. Each player must choose a place to hide and the finder player must discover their locations. The game provides a set of clues about positions based on information gathered by barrels and hoodies. Both game elements are electronic enhanced with a CPU and wireless (*Zigbee*) communication. Hoodies are focused on being lightweight and allow continuous movement of kids. Each of them have a small LED display attached to the arm where game texts are informed (Firgure 2). They also have RFID tags that provides identification to each player. Barrels have RFID readers which identifies nearby players and also calculates its location. These elements allows a very seamless interaction with kids during game sessions. The game has been experimented in both closed spaces, like gyms, and open spaces, like parks with very good results. Although the flexibility of game mechanics for both playing modes designed they limit the number of players. This because the number of rules, defined by the teacher, are limited and the number of players to be found must be limited also.

4.3 SenToy in FantasyA

In FantasyA [Prada et al. 2003] each player embodies a wizard inside a virtual world where emotions controls your actions. This way the player in place of use commands, must use its feelings expressions to interact with game and guide its character. The way emotions are collected is through representing them on a doll named SenToy [Paiva et al. 2002]. This doll contains a set of sensors (Figure 3) which allows to perceive its movements during the game. Analysing these movements is possible to determine the feelings being expressed by the player and the convert them into actions. Doll movements are also used for other types of actions like walking, jumping and collecting items. Using SenToy is possible to observe a limited set of emotions, like happiness and anger, which contains a uniform expressibility among players. Other emotions,

Figure 4: *Players interacting on Touch-Space. [Cheok et al. 2002]*

like disgust, have a greater diversity of expressions which turns them harder to identify. Even though the doll is able to identify the basic movement components of a set of six emotions (fear, anger, surprise, sadness, happiness and disgust) and three other actions. The study of such set is intended to lead to body movement analysis, discarding the need for the toy as interface with the game. Since the game takes place in a virtual world the capability of aggregating a large number of players collaboratively is explored using MMOGs concepts. The usage of emotions as means to interact with users exploit a different dimension of human-computer interfaces that tries to shorten the gap between the system and the user. On the other hand the mechanics of the game (involving a virtual world) doesn't involves real world elements, restricting it to closed space environments.

4.4 Touch-Space

On Touch-Space [Cheok et al. 2002] a deep interaction between players, the real and virtual environment is exploited. The background history of the game is based on two knights trying to save their princess from an evil witch. Through the game three stages must be achieved in order to find the witch's castle and free the imprisoned princess. Each of this stages exploits different concepts of interaction between users and the space surrounding them. To do so, each player is equipped with a HMD that allows them to see both real world and overlaying virtual elements at the same time. They also have augmented "wands" used to interact with the elements (Figure 4). The first game stage challenges players to find the map parts that shows the way to the witch's castle. This parts are hidden in boxes (real world elements) scattered through the room. When a box is opened a object or trap (virtual element) is found. The second stage consist of a air battle where players must hit the witch, that is flying across the room, with their wands. The last part consist on finding the princess inside the caste (full virtual environment) through audio clues. This game makes a great use of mixing virtual and real world elements through each stage. Exploiting augmented reality was possible to allow players to not only feel such blending but also cooperate more seamlessly between themselves. This was pointed out by most of players during experiments but also was complaints about the HMD usage. This happened due to the fact that the device used was heavy and not much natural on use. Other limitations were regarding the usage of location sensors and the game mechanics that placed a boundary to two players and the game to happen only on closed spaces. Besides these games, the following works are considered in this research:

1. **Smart Playing Cards** [Rmer and Domnitcheva 2002]
2. **Touch-Space** [Cheok et al. 2002]
3. **Movement Snake** [Headon and Curwen 2002]
4. **Movement Quake** [Headon and Curwen 2002]
5. **Movement Smash Game** [Headon and Curwen 2002]

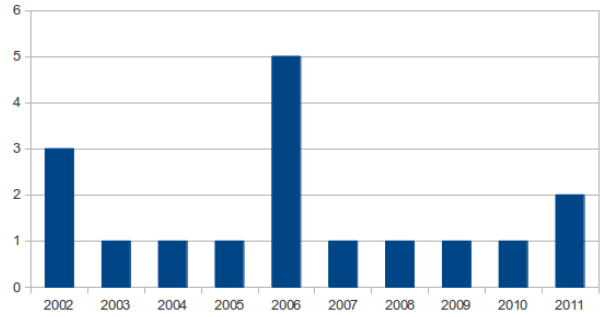

Figure 5: *Distribution os paper samples by year.*

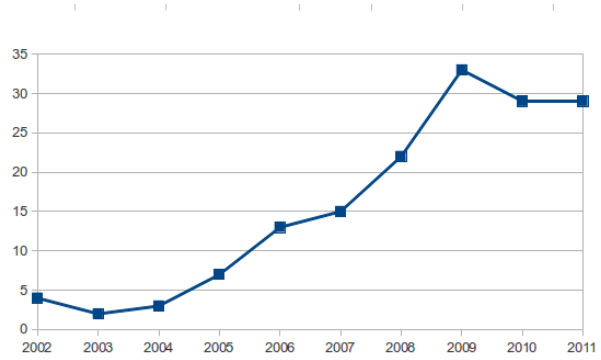

Figure 6: *Ubigames papers published per year.*

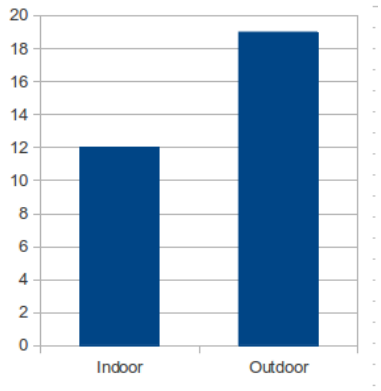

Figure 7: *Type of environment on games.*

6. **FantasyA** [Prada et al. 2003]
7. **Hoodies and Barrels** [Arroyo et al. 2011]
8. **Treasure Hunt NFC** [Garrido et al. 2010]
9. **Drink Some Beer** [Koskinen and Suomela 2006]
10. **Snow War** [Koskinen and Suomela 2006]
11. **Hunters** [Koskinen and Suomela 2006]
12. **Treasure Hunt** [Koskinen and Suomela 2006]
13. **Pre-Emptive Strike** [Koskinen and Suomela 2006]
14. **Speed Biking** [Koskinen and Suomela 2006]
15. **Magic Mushroom Race** [Koskinen and Suomela 2006]
16. **Cannon Game** [Koskinen and Suomela 2006]
17. **iCat (Chess)** [Castellano et al. 2009]
18. **Cron** [Linner et al. 2005]
19. **Target Shooting Bike Game** [Silva and El Saddik 2011]
20. **Save the Princess!** [Mottola et al. 2006]
21. **Moving Monk** [Akribopoulos et al. 2008]
22. **Assassin Apprentice** [Akribopoulos et al. 2008]
23. **Tycoon** [Oppermann et al. 2006]
24. **Hitchers** [Drozd et al. 2006]
25. **Uncle Roy All Arround You** [Benford et al. 2004]
26. **Can you see me now?** [Benford et al. 2006]
27. **Day of the Figurine (DoF)** [Greenhalgh et al. 2007]
28. **Love City** [Greenhalgh et al. 2007]
29. **Professor Tanda** [Greenhalgh et al. 2007]
30. **Mobi Missions** [Greenhalgh et al. 2007]

5 Analysis

The tool used to choose the articles considered in this research was the IEEE-Explore [IEEE 2012] using the keywords “Ubiquitous Games”, “Pervasive Games” and “Context-Aware Games”. This leads to a result of 168 papers in the last ten years from which were chosen the 17 most relevant papers, according to the relevance provided by the search tool, summing 30 games. During sampling, it was ensured that every year of the period had at least one paper chosen (Figure 5). Every paper was also subject to analysis regarding its relevance to the subject, in order to ensure a better quality of the analysis. Observing the distribution of ubigames papers over the years (Figure 6) there is a clear trend indicating academic interest on the subject. This is consistent with the growth of mobile game market over the last decade that have influenced the interest in such applications by the overall community.

5.1 Environment

Figure 7 shows the distribution of the types of environments among the observed papers. Open space projects focuses on wide environments and games with more flexible rules, leading to a greater number of simultaneous players. Most of them (75%) explores multi-player or collaborative strategies. This kind of environment also leads to a strong use of location as context information. On the other hand, closed spaces can take advantage of the controlled environments to explore a greater range of devices and forms of interaction. The spatial limitations ends leading to a small number of players on such games, since most of them (68%) are focused on single-player or team-play strategies. The choice of which kind of environment not only influence the mechanics of the game but also the range of users. This have greater influence on the amount of validation that the project will receive experimentally. For example the game “Uncle Roy All Around You” had almost 300 players during its gaming sessions while “Touch-Space” did not reached 50 users.

5.2 Player Flexibility

The player strategy has a very strong relation with the kind of environment. However Figure 8 shows that none of the strategies have a grater advantage of numbers over others. This shows a well balance between the strategy and the intended dynamic of each game. While single-player and team-play are very restrictive, others allows a greater number of interactions among users. Although multiplayer games imposes limits on how much players are allowed, “Hoodies and Barrels” is limited on the number of kids to be found, collaborative games, like “Uncle Roy All Around You”, provide access to an unlimited[1] number of players simultaneously.

[1]Respecting the limitations of the infrastructure used by the application.

Game	Environment	Player Flexibility	Context Data	Context Data
Smart Playing Cards	Indoor	Team-play	-	Cards (sensor) LPD
Touch-Space	Indoor	Team-play	Location	HMD Boxes (sensor) Wand locators (sensor)
Movement Snake	Indoor	Single-player	Biometric	Sensitive floor (sensor) LPD
Movement Quake	Indoor	Single-player	Biometric	Sensitive floor (sensor) LPD
Movement Smash Game	Indoor	Single-player	Biometric	Sensitive floor (sensor) LPD
FantasyA	Indoor	Collaborative	Feelings	SenToy (sensor) PC
Hoodies and Barrels	Indoor and Outdoor	Multi-player	Location	Hoodie (sensor) Barrel (sensor)
Treasure Hunt NFC	Outdoor	Multi-player	Location	Cellphone NFC readers (sensor)
Drink Some Beer	Indoor	Single-player	Location	Cellphone
Snow War	Indoor	Team-play	Location	Cellphone
Hunters	Indoor	Multi-player	Location	Cellphone Bike (sensor)
Treasure Hunt	Indoor	Multi-player	Location	Cellphone
Pre-Emptive Strike	Indoor	Team-play	Location	Cellphone
Speed Biking	Indoor	Single-player	Biometric	Bike (sensor)
Magic Mushroom Race	Indoor	Multi-player	Location	Cellphone
Cannon Game	Indoor	Team-play	-	Cellphone
iCat (Chess)	Indoor	Sinlge-player	Feelings	Robot (Camera and Screen)
Cron	Outdoor	Team-play	Location	Cellphone
Target Shooting Bike Game	Indoor	Single-player	Biometric	Bike (sensor) LPD
Save the Princess!	Indoor	Multi-player	Location	Motes (sensor) Laptop
Moving Monk	Outdoor	Collaborative	Location and Biometric	Sunspot (sensor) PC
Assassin Apprentice	Outdoor	Collaborative	Location and Biometric	Sunspot (sensor) PC
Tycoon	Outdoor	Collaborative	Location	Cellphone
Hitchers	Outdoor	Collaborative	Location	Cellphone PC
Uncle Roy All Arround You	Outdoor	Collaborative	Location	Cellphone PC
Can you see me now?	Outdoor	Multi-player	Location	Cellphone PC
Day of the Figurine (DoF)	Indoor	Multi-player	-	Cellphone PC
Love City	Outdoor	Collaborative	Location	Cellphone
Professor Tanda	Outdoor	Single-player	Location	Cellphone
Mobi Missions	Outdoor	Collaborative	Location	Cellphone

Table 1: *Classification of the games with respect to the proposed dimensions.*

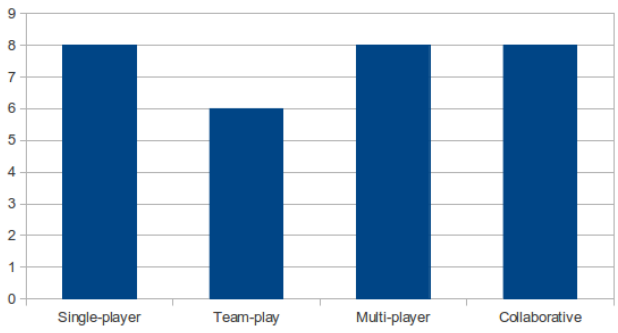

Figure 8: *Player flexibility on games.*

5.3 Context Data

It is through the right usage of context data that games can embody the concepts of ubicomp. From all games considered, only one, Day of the Figurine [Greenhalgh et al. 2007], did not make use of any context-data. Figure 9 shows the distribution among the most common types of data used. Location is clearly the context information most used. It can be found on all of open space games and is mostly used in order to relate actions with real world elements. It is present on almost half of closed space games where it is used for the same purpose but also to allow to direct interaction to the place where the player stands. Biometric data comes in second, with heart-rate sensors, gesture recognition, among many others. Heart-rate sensors are mostly used to correlate physical effort with gaming actions, while gesture recognition is used as a more natural interface with the game. Feelings have very little application on ubigames but they represent a promising context data to reach a human-like interaction with users. It is valid to point out that none of the games provided much information on how players identity is collected. Although many of them clearly relate players to some kind of identification, none of them invested on pervasive means of doing so, like using audio or video information from the environment. Most of them present evidence of gathering the player information through logins or tokens (e.g., cellphones or RFID tags).

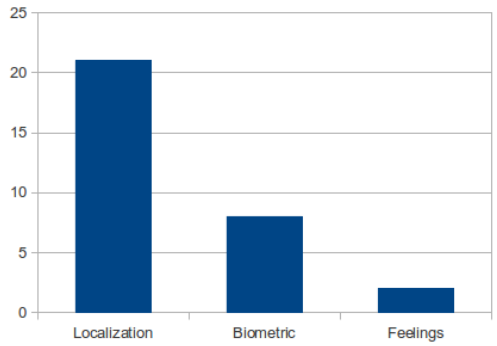

Figure 9: *Context data used on games.*

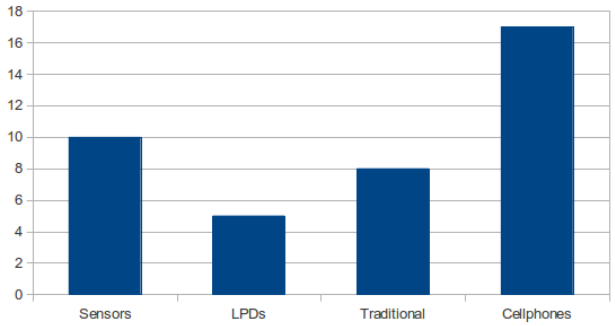

Figure 10: *Common means of user interaction on games.*

5.4 User Interaction

Forms of interacting with users aside from traditional means are essential to ubicomp. The screen, keyboard and mouse triad is the most common human-machine interface, though, they require focus of the user while using them. Ubiquitous computing aims to promote mobile and pervasive communication, thus, traditional interfaces are not the best suited ones for ubicomp. This is why exploring new forms of interaction plays a valuable contribution to the area. The papers considered showed a variety of ways to interact with players and the most common ones were summarized into four groups, as depicted in Figure 10. On the cellphone category were included both smart-phones and PDAs, because their capabilities are very similar. They were also the most used means of interacting with users, encountered on over half of the games studied. The characteristics of mobility and easy access to location data through GPS data plays an important role on this choice. This is aided by the fact that such technology becomes more common in everyday life. The sensor category considered a wide range of devices that varied from heart-rate frequency to accelerometers. This kind of interface was found on a 33% of the games. Heart-rate was used to correlate physical effort with game benefits as shown on "Speed Biking" [Koskinen and Suomela 2006] and "Target Shooting Bike" [Silva and El Saddik 2011]. Accelerometers can be used to detect user gestures, as observed on the "Moving Monk" [Akribopoulos et al. 2008] game. Traditional methods were used in almost 25% of the games, mostly involving single user interaction. This can be found on games such as "Uncle Roy All Around You" where on-line players could provide tips to players on the streets. This restricts the communication to one user at a time, which could be overcome by the use of LPDs. This interface allows the communication with groups of players, displaying public information and alerts. The mechanics of such games are very related to public informations. Many ubigames explored different types of interaction with their players, going beyond the traditional ones. The "Touch-Space" game explored the combination of HUDs and augmented reality through "wands" that enabled users to participate the game while still interacting with the environment and with each other. "Hoodies and Barrels" used jackets and totems for a game developed for children, allowing free movement and quick feedback. The "SenToy" doll provided an easy way for users to express their feelings though body movement representations.

6 Conclusion

The ubicomp vision of an enhanced computed environment becomes a closer reality each day. This is evident with the growth of available devices present on everyday life. Besides this fact, in order to achieve its purpose this research area must focus on aiding users with their tasks. New concepts and technologies are developed with the intent to letting the users focus on their tasks, not on the systems that surround them. Games had been used over the last decade in order to ease the receptivity of users to new kinds of interaction. This work exposed some characteristics that ubigames have in common. The classification of games characteristics contributes to the analysis of new games and the choice of strategies that take advantage of each characteristic. By observing the dimensions presented (Environment, Player Flexibility, Context Data and User Interaction), it is possible to establish a basis of comparison for each game. This allowed to highlight common traits, such as the importance of location as context data, and neglected ones, such as the exploration of identification techniques. Also it pinpoints new paths being explored, as seen with the use of feelings context data. The portrait of this research shows that the scenario envisioned ten years ago is not very far. Since then mobile games became a growing trend in industry, reaching games that use the entire planet as board (e.g., Mayor War [GeoWok 2010]) available for the community. However, the elements of everyday life are not as connected to the virtual world as expected, leaving plenty of room to work on new ways to bridge the two realities.

References

AKRIBOPOULOS, O., BOUSIS, D., EFSTATHIOU, D., KOUTSOURIDIS, 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.

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.

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. Siio, Eds., vol. 3205 of *Lecture Notes in Computer Science*. Springer Berlin / Heidelberg, 70–87.

BENFORD, S., CRABTREE, A., FLINTHAM, M., DROZD, A., ANASTASI, R., PAXTON, M., TANDAVANITJ, N., ADAMS, M., AND ROW-FARR, J. 2006. Can you see me now? *ACM Trans. Comput.-Hum. Interact. 13*, 1 (Mar.), 100–133.

BJRK, S., HOLOPAINEN, J., LJUNGSTRAND, P., AND AKESSON, K.-P. 2002. Designing ubiquitous computing games - a report from a workshop exploring ubiquitous computing entertainment. *Personal Ubiquitous Comput. 6*, 5-6 (Jan.), 443–458.

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. ACII 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.

CRAWFORD, C. 1984. *The Art of Computer Game Design*. Osborne/McGraw-Hill, Berkeley, CA, USA.

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.

GARLAN, D. 2002. Project aura: Toward distraction-free pervasive computing. *Pervasive Computing, IEEE*.

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.

GEOWOK, 2010. Mayor war. Available at `http://mayorwar.com/` (accessed at 07/12/2012).

GREENHALGH, C., BENFORD, S., DROZD, A., FLINTHAM, M., HAMPSHIRE, A., OPPERMANN, L., SMITH, K., AND VON TYCOWICZ, C. 2007. Addressing mobile phone diversity in ubicomp 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.

HEADON, R., AND CURWEN, R. 2002. Movement awareness for ubiquitous game control. *Personal and Ubiquitous Computing 6*, 407–415.

IEEE, 2012. Ieee-explore. Available at `http://ieeexplore.ieee.org/` (accessed at 07/12/2012).

JANSEN, S. H. W. M. H. E.-Z. J. K. Y. K. E. 2005. The gator tech smart house: A programmable pervasive space. *IEEE Computer magazine*.

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.

KRUMM, J. 2009. *Ubiquitous Computing Fundamentals*. Chapman & Hall/CRC.

LAW, F. L., KASIRUN, Z., AND GAN, C. K. 2011. Gamification towards sustainable mobile application. In *Software Engineering (MySEC), 2011 5th Malaysian Conference in*, 349 –353.

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.

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.

OPPERMANN, 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.

PAIVA, A., ANDERSSON, G., HK, K., MOURA?O, D., COSTA, M., AND MARTINHO, C. 2002. Sentoy in fantasya: Designing an affective sympathetic interface to a computer game. *Personal and Ubiquitous Computing 6*, 378–389.

POPE, S. 2006. The future of head-up display technology. *Aviation International News 38*, 1.

PRADA, R., VALA, M., PAIVA, A., HOOK, K., AND BULLOCK, A. 2003. Fantasya ? 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.

ROLLINGS, A., AND MORRIS, D. 2003. *Game Architecture and Design: A New Edition*. New Riders Games.

RMER, K., AND DOMNITCHEVA, S. 2002. Smart playing cards: A ubiquitous computing game. *Personal and Ubiquitous Computing 6*, 371–377.

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.

WEISER, M. 1991. The computer for the 21st century. *Scientific American*.

WEISER, M. 1993. The world is not a desktop. *ACM Interactions*.