5
The domain knowledge mapping

When studying the literature on pervasive games and related projects, we notice that several works refer to the concept of *pervasiveness* in an implicit way. In general, maybe due to the inconsistency of terms and confusion of definitions, the concept of *pervasiveness* is taken for granted.

We understand "pervasiveness" as *a fundamental property of pervasive mobile games, meaning something making the game "spreading through", "diffuse", "highly present" in the virtual and physical worlds*.

Some authors, as Nieuwdorp (2007), also share concerns with the concept of pervasiveness in pervasive games. In her work, Nieuwdorp has analyzed the jungle of terms and definitions for pervasive games, ending up with a question "*what makes a game pervasive*", suggesting that there is a property of *pervasiveness* as being the "*characteristic that occurs in different perspectives and levels of intensity and can be applied to different genres, games, and play.*" (Nieuwdorp 2007). However, it seems that she has stopped at that point.

In this regard, we have investigated the literature and game projects to find patterns and features that would help in characterize pervasiveness and pervasive mobile games (considering the boundaries discussed in Chapter 4). This research work has produced knowledge about the domain of pervasive mobile games that is organized as follows:

- A "pervasive game features"[73] list, and descriptions of each item;
- A set of *verification questions* for each pervasive game feature;
- A list of perspectives to group pervasive game features into certain views;
- A categorization scheme for the concept of *pervasiveness*.

Table 5.1 presents a compact view on the pervasive game features list[74] we have identified. This list this research work represents a first attempt at defining

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73 Although the term "feature" has several meanings in Software Engineering, we believe that "pervasive game features" is the best term to be used in our methodology.
74 The list is presented in tabular format for providing a compact view on the items.

important features in a pervasive mobile game. We do not claim this list contains all possible features – a more definitive pervasive feature list would require further investigation about design theory and extra inspections using different game and software designers.

Local space redefinition	Game object tangibility	Game pacing	Connectivity
Mobility	Game content adaptability	Daily life interleaving	Game autonomy
Device independence	Cross-mediality	Uncertainty handling policy	Social communication
Involving non-players	Conformance to physical and social settings	Usability	Persistency

Table 5.1: Pervasive game features list in tabular format

For each pervasive game feature, there is a checklist. Designers can use checklists to help in identifying features in an existing pervasive mobile game, or as guidance to introduce them in new game projects. Appendix B presents the complete checklists for all features of Table 5.1.

Section 5.1 presents a brief discussion on the pervasive game features. Appendix B also provides a more detailed discussion on them[75]. Section 5.2 presents the perspectives for pervasive game features. In this work, each pervasive game feature perspective concerns itself with a different aspect of the pervasive game. Section Error: Reference source not found presents a discussion about how pervasive game features and software requirements can be related. Section 5.4 presents a categorization scheme for pervasiveness. Finally, Section 5.5 describes how the pervasive game features are present in *Pervasive Word Search*, our prototype.

Other researchers have tried to investigate how pervasive games differ from traditional digital games, as Guo and co-authors (2010), by characterizing important aspects of pervasive games into a conceptual framework. In their framework TeMPS, Guo and co-authors (2010) propose a set of four perspectives that they consider as important to differentiate pervasive games from traditional digital

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75 When presenting the pervasive game features, this chapter references several games, which have been summarized in Table 4.3. Appendix A provides detailed descriptions of those games.

games. They have named their perspectives as temporality, mobility, perceptibility, and sociality[76]. For their perspectives, they propose some properties that could characterize the perspective. As an example, Guo and co-authors (2010) propose the following options for their "mobility" perspective:

> "Three options are available for the Mobility characteristics.
> - Games are played fixed in one place as most traditional computer games are;
> - Games can be played in large-scale outdoor places anywhere (often also played in everyday life); or
> - Games can be played where the player must move in one place and need physical actions to change gesture, posture, and etc due to requirements of gameplay."

This work differs from the work by Guo and co-authors (2010) in several ways. Their notion of perspectives is similar to the one used in this work (in regard to separating concerns), but we provide more detailed discussion, features discussion (which they regard as simple "options"), and additional perspectives. For example, we include the notion of *accessibility* as an important perspective to consider in pervasive mobile games, and provide several examples of how a pervasive feature occurs in several games. Another important difference is that their discussion is geared towards design studies, whereas our discussion is geared towards technological aspects[77]. We also provide a number of detailed checklists to verify if a feature has been met in the design, which is something that does not apply to the work by Guo and co-authors (2010).

5.1
Pervasive game features

This section presents the pervasive game features we have identified.

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76 Guo and co-authors (2010) provided additional descriptions for their perspectives, as*: "addressing the temporal property about the game"* (temporality), *"addressing the spatial property of the game"* (mobility), *"addressing how the game is mixed with the reality"* (perceptibility) and *"addressing the player's relationship and social influence of the game"* (sociality).

77 For example, aspects related to computing, pervasive computing, input and output devices, networking, sensors, and actuators.

5.1.1
Local space redefinition

This feature refers to transforming the physical space where the game happens into the "game world". This transformation may happen as:

- A design decision (by augmenting the physical world with technology, references to physical locations, etc.) or;

- Indirectly, as a consequence of the game activities.

This feature closely relates to the idea of "games coming back to real-world" found in the literature of pervasive games.

Waern and co-authors (2009) present a related notion, "authentic environments", which allows "the participants to physically act in a near-perfect representation of the game world", being one of the elements that help in bringing immersion to a pervasive game.

5.1.1.1
Physical aspects of local space redefinition

An aspect of using *Local Space Redefinition* as a design decision relates to incorporating technology into a place to support the game, deploying sensors, actuators, and deploying wireless networking (in some cases) to the environment. In this regard, the game area needs to be prepared for a game session, which is characteristic of event games (please see Section 5.1.7). This is the approach of *Pirates!*, *Pervasive Clue*, *Manhattan story mashup*, *PAC-LAN*, and *REXplorer*.

Another aspect refers to using tangible objects to interact with the game. This is the subject of Section 5.1.2. Pervasive games can use this resource to reinforce the local space redefinition. This is the approach of *Gigaputt* and *REXplorer*.

Another alternative is incorporating existing local objects (statues, squares, building, etc.) as part of game activities. This is the approach of *Uncle Roy all around you*, *Gbanga Famiglia*, and *Mythical: The Mobile Awakening*. For example, in *Mythical: The Mobile Awakening* characters related to water appear

when the player is near lakes or shores. From a technology point of view, those approaches have several advantages, as:

- The landmark possibly is a "big" object (area-wise) and has a known (fixed) location in the world. This may minimize problems with errors related to location systems, being an attempt to match the precision of the technology to the game activity;
- Game designers may use ambiguity to refer to the landmark ("go near the statue ..."), meaning that the game can deliberately embody technology imprecision into the gameplay, instead of referring to a precise location;
- It is a way of reshaping the local space, possibly improving the player immersion with the game, adding up a "fantasy factor" to the gameplay.

Another physical resource that games may apply is introducing human actors as live non-player characters. This is the approach by *Uncle Roy all around you*, and *Can you see me now*?.

5.1.1.2
Metaphorical aspects of local space redefinition

This relates to the game causing redefinition of local space as a consequence of the game activities[78]. In this regard, players come to see the local places through the alternate lens of the game. Sotamaa (2002) refers to those aspects as "social construction of space".

All games we have analyzed have some aspect of this. While with physical place augmenting this becomes more noticeable, other games that do not use physical augmenting present this on subtle ways. This is often the case when the game uses local context as a source of gameplay, like: *Insectopia*, *Gigaputt*, *Tycoon*, *Ere be Dragons*, *Feeding Yoshi*, *Botfighters*, and *Mythical: The Mobile Awakening*.

For example Peitz and co-authors (2007) reported that during *Insectopia's* research, a player *"specifically went to a familiar library to play this game just because she knew that there were many laptops in there"*. In this sense, the library

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78 As something that has not been planned by the game designers.

has been incorporated in the game, being transformed in a game space where some particular insects would be present[79].

5.1.2
Game object tangibility

This feature relates to how the game uses the mobile devices (and other environment elements) as tangible objects, instead of being mere terminals. As tangible objects, we mean that the device has a purpose (a role in the game), and players manipulate them as game objects instead of terminals (*e.g.* "only phones").

Ishii and Ullmer (1997) defined the "tangible object" metaphor for "human-machine interfaces that couples digital information to physical objects". For example, on a general context, this could be pieces of augmented table-top games (Magerkurth *et al.* 2005). With smartphones, this could be achieved through designing interactions based on built-in sensors and actuators. For example, gestures (accelerometers, camera), haptics feedback (vibration), "scanner metaphors" (*e.g.* using network technologies as Bluetooth, and WiFi).

Existing research works (Waern *et al.* 2009; Tuulos *et al.* 2007; Lindt *et al.* 2005) suggest that this feature contributes to increase player immersion in the game.

The games in *The Audio Flashlight* prototype series (Appendix C) apply this to transform the mobile phone into an "audio flashlight" manipulated through gestures. Other games that use tangible objects are *Pervasive Clue*, *Gigaputt*, *REXplorer*, *Manhattan story mashup*, *Epidemic Menace*, *Songs of North*.

The device could also be disguised as another object through shells and other resources, but the applicability of this approach should be analyzed as it could decrease game accessibility[80]. *REXplorer* and *Pervasive Clue* use this approach.

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79 The main idea in *Insectopia* involves going around places to collect virtual insects, which the game create using nearby Bluetooth devices as sources.

80 The "accessibility" concept as described in Section 5.2. In this example, players can only play those games by contacting the developers directly and getting the devices, which limits the reach (accessibility) of those games.

Research works (Waern *et al.* 2009; Ballagas *et al.* 2008) suggest that using multiple props (physical game objects) in the game might improve social communication, immersion, and the game experience. This means using several devices as game objects, with complementary functionalities[81]. Our prototypes *The Audio Flashlight 2, 3* and *5* use this approach. Other games that apply this idea are *REX-plorer* and *Epidemic Menace.*

5.1.3
Game pacing

This feature relates to how technology influences or limits the pacing of the game. For example, some technologies do not work well if the player is moving above some threshold speed, or some technologies may not provide responses in a real-time fashion that might be required by some games. In those cases, it is necessary to design game activities that are compatible with these technology characteristics. This mainly concerns networking technologies and sensors used to detect nearby objects. Examples of games where pacing has affected networking technologies are *Feeding Yoshi* and *Hitchers.*

Examples related to sensors include GPS and Bluetooth. GPS sensors can take a long time (like several minutes) to get the first satellite connection and be available to the user. This also happens when the sensor has to re-acquire the connection. Among affected games is *Can you see me now?*. Some games use Bluetooth as a source for game content (as *Insectopia* and our prototype *Pervasive Word Search*). However, searching for Bluetooth devices takes a long time, considering timing conditions of some game activities. In our experience this operation might take around ten seconds in some cases.

Other games try to adapt to those issues by using a deliberately slow-gameplay, relying on asynchronous play and updates. This is the case of the game *Day of Figurines*.

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81 Please refer to *The Audio Flashlight 2* prototype in Appendix C.2 for an example.

5.1.4
Mobility

Considering mobile phones, Mobility is a default feature of pervasive games. In the context of this research, this feature relates to aspects of portability (not using networking) and mobile computing – using wireless connections on mobile devices – and also aspects pertaining to the physical size of the game area, which may require players to move.

We consider as "the highest level of mobility" the situation where a game is portable, has plenty of network resources available (regarding quality of service and availability), and uses those resources in the game activities.

In pervasive games, the requirement of movement in game space varies greatly. Some games are restricted to small areas (as *Pirates!*), other to some controlled parts of the city or place (as *Uncle Roy all around you*, *PAC-LAN*), and other to very big (mostly unrestricted) areas (as *Botfighters*, *Insectopia*, *Mogi, Gigaputt, Gbanga Famiglia, Seek n' Spell, GEO Hunters*).

The scale of the potential game area greatly influences its realization. For example, games with potential big areas benefit greatly from using mobile phones as those devices are able to use networking anywhere there is coverage from the cellular operator. In this regard, developer can rely (theoretically) on an infra-structure that is already available. For smaller scale areas, the developers might be able to provide a more customized game experience, as in *PAC-LAN*. This also may help developers in handling limitations of technologies, like network availability and coverage.

Another interesting aspect regarding Mobility is whether the game fosters players to move. The motivation for this varies. For example, it could be to stimulate physical exercise (as *Ere be dragons*), having players to be in places with lots of people (our prototypes *The Audio Flashlight 4* and *Pervasive Word Search*), tourism (*REXplorer*). Other games might constrain movement to certain areas to handle technology limitations better (as *PAC-LAN, Pirates!, Uncle Roy all around you*).

5.1.5
Game content adaptability

This feature relates to the context-awareness part of games, meaning how games are able to adapt the gameplay to different places, providing the same (expected) experience regardless of the environment. Games that rely heavily on sensors for dynamically-generated content are the candidates to have high game content adaptability. Our prototype *Pervasive Word Search* relies on camera, Bluetooth devices, WiFi access points, and light sensors to generate the game content.

Other noteworthy examples of games that generate content from the environment and adapt the gameplay are *Insectopia*, *The Journey*, *Tycoon*, *Feeding Yoshi*, *Seek n' Spell*, *Gigaputt*, *Hitchers*.

One important issue related to games that use context to generate content relies on the availability of content sources. For example, games that use WiFi access points or Bluetooth devices may assume that those resources will be highly available. Regarding WiFi, the distribution of access points varies greatly. A business area may have a much higher density of WiFi access points than residential and rural areas. In those cases, the experience of the game might be greatly affected. Those kinds of pervasive games should balance this issue, which we call "evenly-distribution of content".

5.1.6
Daily life interleaving

This feature refers to the game existing as a "parallel world" (persistent), where players are able to join and exit anytime, with game playing becoming diffuse in daily life. This relates to ways that games would be mixed with other non-game activities of players. The most prominent aspect of this is the possibility for a player to engage with a process that evolves continuously over time (and does not depend whether the player is connected to the game or not). In fact, creating a pervasive game with this feature requires designing around a persistent game world, which may be accessed "anywhere".

Issues related to this are creating game activities that can be interrupted any-time. In case of mobile phones, this also concerns the fact that those devices were designed primarily as communication tools, and thus are subject to receiving phone calls and text messages anytime. Those are higher priority events that game activities should take into account. As players are possibly moving other kinds of interruptions may arise, such as: a train has arrived, the player has met a friend, etc. (Saarenpää *et al.* 2009).

Some authors, as (Saarenpää *et al.* 2009; Flintham *et al.* 2007b), propose creating "asynchronous gameplay", which means the game is turn-based. This is the case of *Day of figurines* and *Mythical: The Mobile Awakening*.

A related concept is designing "short game sessions", when players are able to join the game, play quickly, and exit. Although not a persistent game, *Insecto-pia* applies this approach.

In these games, communication between the player and the game world is an important issue. As the game exists independent from player actions, the game should provide a way for players to know about game events that might affect them. *Day of figurines*, for example, sends SMS messages to players, which is a direct method. Mobile phones are suitable for this kind of communication. Other methods are indirect, meaning that the players should log in to the game, or con-sult external media (like web pages) to check about the game status. Indirect methods require active participation from players, while direct methods do not.

5.1.7
Game autonomy

This feature relates to the game as being an independent system, which does not require preparation for game sessions (like configuring the physical location) or in-game management by a support team. Contrasting to this are the "event games" – pervasive games that happen at specific time and physical places, for a specific duration. Event games share some of the following characteristics:

- References to local physical context (specific addresses, statues, build-ings, etc.) are part of the game;

- The game area is constrained;
- The place is augmented with technology (as sensors) that enables important gameplay features. This step ("place configuration") happens before game sessions;
- Uses human actors as live non-player characters;
- Requires a support staff to supervise the game as it happens, working to keep player experience as smooth as possible, possibly intervening in the game to handle issues so players do not notice them;
- May require specific hardware (sensors, playing devices, etc.);
- Requires local wireless networking.

Event games are alternatives for providing unique experiences to players. They are also alternatives to handle technology limitations, by designing games to be deployed on "controlled environments". Examples of event games: *Can you see me now?*, *Pirates!*, *Uncle Roy all around you*, *REXplorer*, *Epidemic Menace*, *PAC-LAN*, *Manhattan story mashup*.

Games that are highly autonomous usually generate content dynamically, as in the discussion of Section 5.1.5.

5.1.8
Device independence

This aspect refers to the game being available on various mobile phone platforms, as the same service.

One alternative is using common frameworks that are available for multiple mobile phone platforms, as do *Insectopia* and *Mythical: The Mobile Awakening*. Another alternative is developing different clients for each platform, as *Mogi*, *GPS Mission*, and *Gbanga Famiglia*.

Besides those alternatives, achieving device independence is not a trivial task in practice, due to the varying characteristics of mobile phones, as different screen sizes, display color depths, input methods, CPU processing, and other

things, even in the same platform[82]. When this happens for devices with the same platform (as Android, or Symbian), this is called "device fragmentation".

5.1.9
Cross-mediality

Cross-media games are games that spread across different devices and media. However, those games are not "multi-platform". A multi-platform game means that it runs on many devices in the same way (or provides very similar service). In cross-media games, the devices have distinct roles in the gameplay, meaning different modes of participation for players. Often, the roles are complementary, meaning the players have to use all of them to complete game tasks.

Usually, those games use a combination of stationary and mobile devices. Examples include *Can you see me now?*, *Uncle Roy all around you*, *Manhattan story mashup*, *Mogi*, *Botfighters*. An example of comprehensive cross-media game is *Epidemic Menace*, which had seven different game devices or interfaces to the game.

Another feature some cross-media games present is using tangible game objects (Section 5.1.2).

Cross-media games represent borderline cases in the conceptual model defined in this work.

5.1.10
Uncertainty handling policy

Technologies have inherent limitations regarding precision, accuracy, availability and other uncertainties. Hence applications relying on technology have to deal with those issues eventually. This feature refers to which strategies the game applies to handle technology limitation issues. This affects mainly sensors and networking.

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82 Not to mention the variety of operating systems available for mobile platforms. Some current (2011) examples for mobile operating systems could be Android, iOS, Symbian, Blackberry OS and Windows Phone.

Another related issue concerns trying to overlay the virtual world over the physical world, because sensor technologies ignore boundaries in the physical world. An example would be having an indoor location technology recognize precisely the physical environment boundaries, which is hard in practice[83].

Some researchers (Bell *et al.* 2006; Benford *et al.* 2006a) have identified five general strategies to handle technology limitation issues related to sensors and networking:

- *remove*: designing activities so that limitations never appear in the game. This includes using improving technologies (which is not always possible) or designing activities that fit the technology limitations into them;

- *hide*: anticipating issues and "correcting" them before the player has a chance to face it. Contrary to the *remove* strategy, in this case the limitations appear in the game, but are "corrected" before the player notices them;

- *manage*: includes having fall-backs to use when the primary mode of operation fails. In other words, the game adapts to the circumstances by having several modes of operation;

- *reveal*: consists of presenting the limitations to users and letting them device how to act. For example, mobile phones display the operator signal strength in the user interface;

- *exploit*: means acknowledging the existence of issues and integrating them into the game as a feature.

Please refer to Appendix B.10 for a detailed discussion on alternatives to handle technology uncertainties.

5.1.11
Social communication

This feature refers to how the pervasive game is able to innovate in fostering social communication, acting as a medium for people to communicate. It includes means for communication between co-located people, distributed people, or both. For example, this includes providing means for players to communicate inside the

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83 In our case, this has been verified while developing the *Location-based quiz* prototype.

game (*Mogi, Uncle Roy all around you, Can you see me now?, Gbanga Famiglia*), inducing players to engage (*Pirates!*), complementary roles in players activities (*Epidemic Menace*, our prototype *The Audio Flashlight 2*), or generate missions for other players (*GPS Mission*).

5.1.12
Involving non-players

This feature relates to integrating non-players into the game. Some games might use this to create ambiguities about who is playing and who is not, helping to create what Montola and co-authors (2009) have defined as "social expansion". This include using actors in the game as live non-player characters (*Can you see me now?*, *Uncle Roy all around you*), and using people as indirect sources of game content (*Insectopia*, our prototypes *The Audio Flashlight 4* and *Pervasive Word Search*).

5.1.13
Conformance to physical and social settings

This feature refers to ethical and privacy concerns, conforming to social conventions, and adequacy to physical settings.

It also involves issues like game activities causing embarrassing situations to players and non-players, safety concerns (as players are usually moving in public places like cities), and whether players might have problems to interact with the game due to the physical place characteristics. An example of the latter is games using audio being played on public noisy places (as *Pirates!* and our prototype *The Audio Flashlight*).

5.1.14
Usability

This feature refers to traditional usability issues from Human-computer Interaction, focused on mobile phones and issues related to mobility. For example, players often have to move, and looking at the device screen frequently might risk

their safety, or may make them miss part of the game experience. Some authors refer to this approach as "design for 'heads-up' experience" (Ballagas and Walz 2007). Examples of games that include this latter concern are *Feeding Yoshi*, *Songs of north*, and *REXplorer.*

5.1.15
Persistency

Persistency refers to maintaining game state to be accessed through different game sessions over time. It directly influences several pervasive features, as Local space redefinition (*Hitchers),* Daily life interleaving *(Insectopia, Day of figurines*), Game autonomy *(Insectopia),* Social communication (games that form communities, as *Mogi, Gbanga Famiglia*). It also relates to Connectivity and Mobility, as players need to access game data from a variety of places, and possibly moving.

This feature is a requirement for games that aim at simulating a parallel world that evolves by itself. This includes all games that have social networking or community aspects.

Not all games require persistency. For example, event-games (*Can you see me now?, Manhattan story mashup, Uncle Roy all around you) and pervasive games that rely only on context-awareness (our prototype Pervasive Word Search).*

5.1.16
Connectivity

This feature influences all pervasive features where obtaining remote information may be required. This includes Mobility, Local space redefinition, Daily life interleaving, Social communication, Game autonomy. It is related to Uncertainty handling policy (as Connectivity is not reliable/available everywhere) and Game pacing (the pacing might influence Connectivity behavior).

Connectivity may exist in global or local scope. Global scope refers to connecting to remote peers that are not in the same physical place. Local scope refers to connecting to peers that are co-located.

Connectivity scope directly relates to the space scope of the game. Global connectivity makes it possible for activities to happen in very different places, possibly very distant. The game space scope is possibly big. Local connectivity restricts activities to happen in small (restricted) places.

5.2
Pervasive game feature perspectives

We organize the pervasive game features list into perspectives that we identified as relevant for pervasive mobile games: spatiality, sociality, availability, accessibility, sensor capability, and immersion.

The idea for organizing the perspectives comes from *aspectual decomposition*. As Czarnecki (1999) points out, the idea of aspectual decomposition is "*to organize the description of a concept (e.g. a system, a domain, a component, a function, etc.) into a set of perspectives, where each perspective concerns itself with a different aspect and none of which is itself sufficient to describe the entire concept*".

Spatiality refers to aspects related to the physical space usage. For example, it includes how the game defines its "gaming space", how the game influences the physical space, and how the physical space influences the game.

Availability refers to how the game is available for players. This has a temporal connotation.

Accessibility refers to how players are able to access the game. It relates to the game reach. In this sense, we consider "accessibility" as having a wider scope than the usual definitions that focus on social issues. Hence, in this work accessibility refers to issues from these three groups:

- Social issues (*e.g.* people with disabilities, gender-biased content);
- Economic issues (*e.g.* expensive devices, services, technology);

- Technological issues (*e.g.* technical constraints, technology not wide-spread).

Sociality refers to the social aspects and social implications of the game. For example, it includes aspects as privacy, ethical issues in the game, how people relate with each (and how the game influences this), among others.

Sensor capability refers to aspect related to "context-awareness", or how those aspects promote context-awareness, or how they are affected by context-awareness.

Immersion refers to aspects that relate/promote/affect the immersive experience the game provides. For example, it relates to the concepts like player engagement and presence, which the latter being discussed in Chapter 2.

Figure 5.1 illustrates the pervasive game features along with the perspectives. Some of the features appear in several perspectives, as they influence those perspectives in different ways. Also, some perspectives influence others.

5.3
Pervasive game features as software requirements

The pervasive features and perspectives can be useful for discovering or defining functional and non-functional requirements for the software part of the pervasive mobile game.

Some of the features might be used to inspire game ideas that may lead to functional requirements. For example, a game might apply *Local space redefinition* to create special "game zones" in the physical space. This is the case of our prototype *Pervasive Word Search*, which creates three types of game zones (wireless, open, dark) in the physical environment.

Other pervasive features might relate to non-functional requirements. For example, the *Uncertainty handling policy* might specify requirements for accuracy, response time, and other "quality" factors.
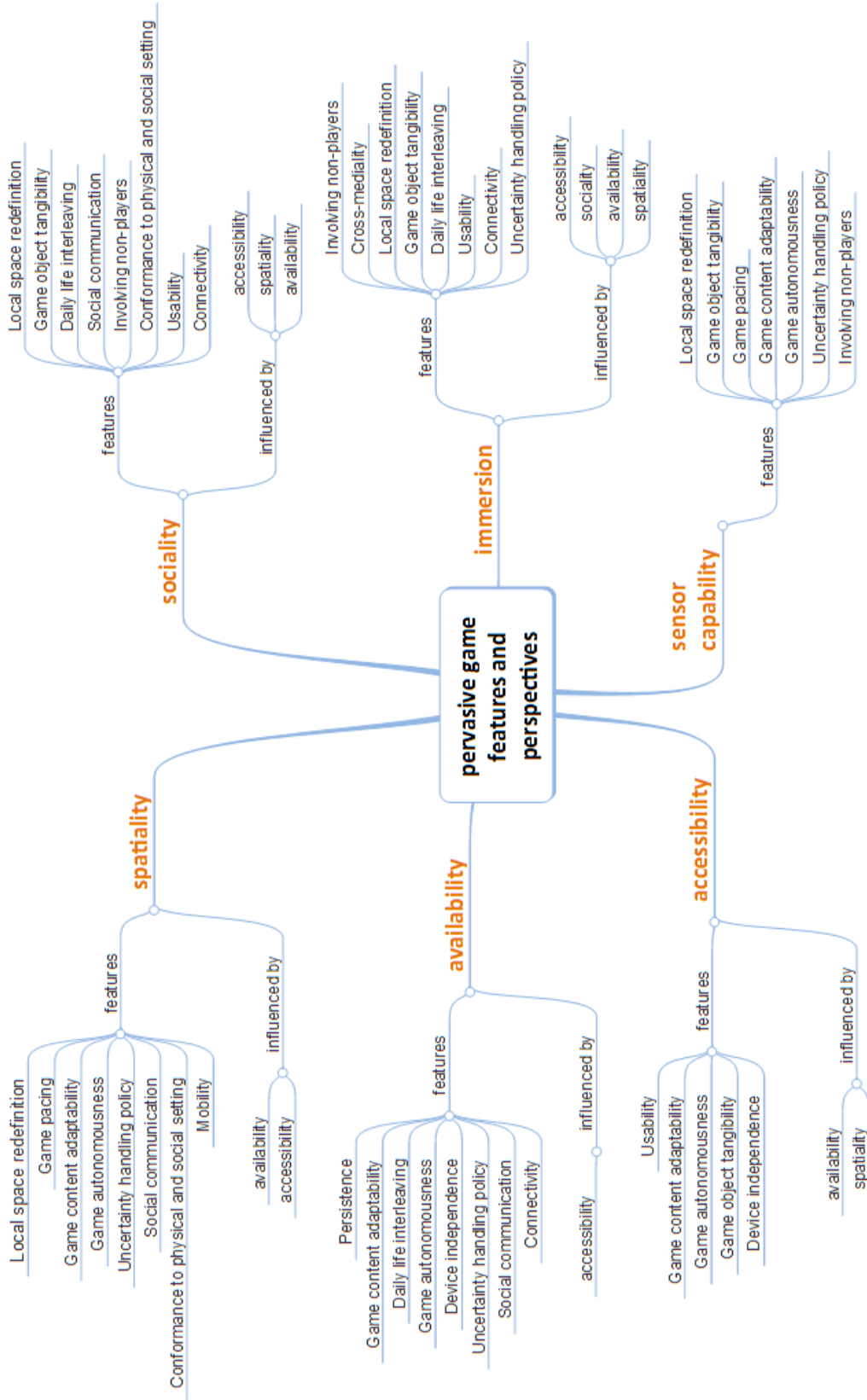
Figure 5.1: Pervasive game features (gray) and perspectives (orange)

In this sense, the pervasive features can be used to design pervasive mobile games considering non-functional requirements from the start. As Chung and Leite (2009) point out, non-functional requirements place restrictions on how the desired functionality can be implemented, not being something that could be considered on a later stage of project development (without possibly bringing lots of costly changes). Hence, integrating non-functional requirements and the desired functionality is crucial. By considering pervasive game features up front, it is possible to discover and consider non-functional requirements from the beginning.

This categorization of pervasive game features and perspectives resembles the ideas behind the concept of non-functional requirements (NFR) catalogs (Chung *et al.* 1999), defined in Requirements Engineering. NFR catalogs provide a way to organize the terminology and classification of concepts related to non-functional requirements.

5.4
Pervasiveness as a radial category

After analyzing the literature on pervasive games, we have concluded that defining an objective criterion for pervasiveness is a difficult task, due to the different viewpoints and background from researchers (social sciences, design, computer science, etc.), and subtlety of the term "pervasiveness". There are attempts to create numerical metrics for evaluating pervasiveness in pervasive games, as (Guo *et al.* 2010), but those are often of subjective nature.

Therefore, we argue that there is a state for pervasive games where pervasiveness is at its highest expression. This would be the idealized case, something that is intangible from a theoretical and practical viewpoint. This notion is "similar" to the state other authors refer as the "ultimate ubiquitous computing form" (Lyytinen and Yoo 2002):

> "In its ultimate form, ubiquitous computing means any computing device, while moving with us, can build incrementally dynamic models of its various environments and configure its services accordingly."

In this case, we consider pervasiveness as discussed at the beginning of this chapter: *a fundamental property of pervasive mobile games, meaning something*

making the game "spreading through", "diffuse", "highly present" in the virtual and physical worlds.

Motivated by Lakoff's radial categories (1987), we represent the universe of pervasive mobile games as a radial category with the ultimate pervasive state as the central case, while concrete pervasive mobile games examples are variations of it. Figure 5.2 illustrates this scheme.
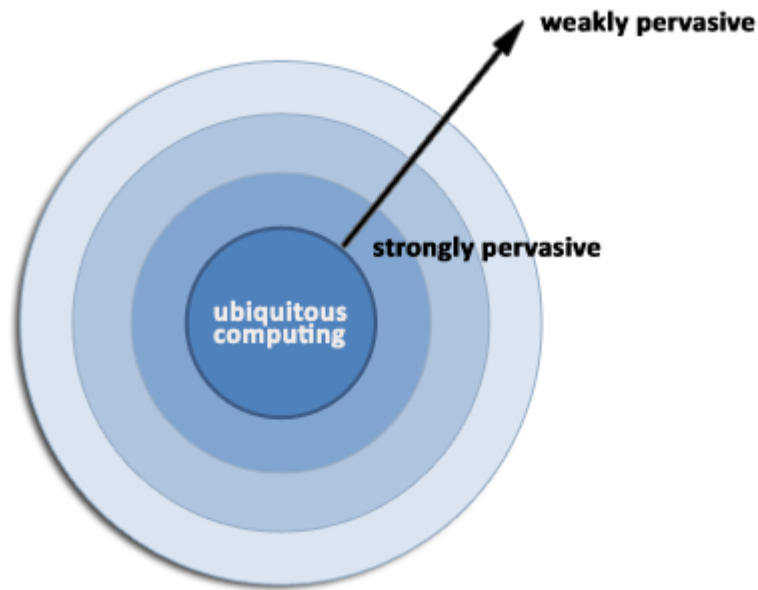
Figure 5.2: Radial category for pervasive mobile games

Radial categories are a categorization scheme proposed by Lakoff, based on idealized cognitive models. An "idealized cognitive model" is a structure to organize knowledge of categories. For example, the idea of "week" is motivated by some conventions[84] and makes it possible to categorize the seven days of the week, work days (Monday … Friday) and weekends (Saturday, Sunday).

In the case of radial categories, there is a central case that is the prototype of the model, along with variations based on it. The central case determines the possibilities for variations. The variations are not generated by rules, but based on conventions. However, those conventions are not arbitrary.

As conventions for this radial category, we use the *pervasive game features* discussed in this chapter. The ultimate pervasive mobile game case has all pos-

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84 For example, natural cycles of days (as determined by the sun), conventions to determine day length (24 hour clock), etc.

sible pervasive game features, including the ones we have identified. The omission of features makes the pervasive mobile game more distant from the central case.

The idea for this scheme is similar to the one Goel and Pirolli (1989) have employed to characterize the "design problem space". They had identified eight invariants characteristics across all design situations which can be used to identify other cases of design and to establish a prototypical, central case.

As we mentioned at the beginning of this chapter, we do not claim that our pervasive game features list is the ultimate one, and we are not trying to propose a definitive definition of pervasive games based on that list. A more definitive list of features would require further investigation about design theory and extra inspections using different game and software designers. We see our pervasive game feature list as a pragmatic roadmap to navigate on the sea of pervasive games, identify noteworthy characteristics, identify pervasive games, inspire novel game ideas, and establish guidelines for game design and software development.

5.5
Example: pervasive game features

Table 5.2 presents how pervasive game features are present in *Pervasive Word Search.*

5.6
Summary

While trying to understand the concept of *pervasiveness* and what characterizes pervasive mobile games, we had conducted research that has produced knowledge about the domain of pervasive games. This knowledge has been organized in four parts:

- A list of sixteen "pervasive game features", and descriptions of each feature;
- A set of *verification questions* for each pervasive game feature;

- A list of perspectives to group pervasive game features;
- A categorization scheme for the concept of *pervasiveness.*

Feature	Description
Mobility	Can be played everywhere. Moving in the physical world is required to play.
Local space redefinition	Places become the source of content. There are several game zones in the real world: wireless zones, dark zones, open zones.
Game object tangibility	Not very strong, but the device can be seen as a tool to capture letters in the world.
Game autonomy	Very high as the game does not require setup, infra-structure.
Game adaptability	Very high, the game draws all content from sensors.
Involving non-players	Non-players are passive from the game point of view. They participate in the game as sources of content, as their Bluetooth devices are sources of letters.
Game pacing	Adjusted to meet the uncertainty handling policy. It is a dynamic pacing as players are required to walk in search for the letters.
Uncertainty handling policy (UHP)	• Hide ▫ The colors are represented with a limited set of options. Similar "colors" then are grouped with the same name (*e.g.* all variations of "red" are considered as "red") ▫ Bluetooth and WiFi queries are slow operations. It is also possible that some queries miss some devices, or return false positives. Thus, the game does not require real-time response to use this data. The interaction with those sensors is indirect – the game queries the sensors in the background and announces the results when they are ready. ▫ The representation of the zones is ambiguous – it does not display a map of the zones, the game just tells if the player has entered or left a zone – for wireless, dark, or open.
Daily life interleaving	Not possible in the game.
Device independence	Limited to Nokia smartphones with Qt.
Cross-mediality	Not applicable.
Social communication	The game stimulates players to go to areas with groups of people. It does not require players to approach/interact with those people, though. If there are more people, the game becomes easier as the time runs slower.
Conformance to physical and social settings	Not evaluated in this game.
Usability	Not evaluated in this game.
Persistency	Not applicable to this game.
Connectivity	The game queries Bluetooth and WiFi networks, but does not establish remote connections.

Table 5.2: Pervasive game features in *Pervasive Word Search*

This chapter has provided a brief discussion on the pervasive game features list, while Appendix B provides a deeper discussion on them and provides check-lists for verifying pervasive game features.

The pervasive game features are grouped into a set of pervasive game feature perspectives – a set of relevant aspects in pervasive mobile games: spatiality, sociality, availability, accessibility, sensor capability, and immersion.

The pervasive game features and perspectives can be useful for discovering or defining functional and non-functional requirements for the pervasive mobile game. They also can help in considering non-functional requirements from the beginning of the project, something that has been found to be crucial in the literature on Software Engineering.

We have concluded that the concept of pervasiveness is diffuse and difficult to define formally, maybe due to the inconsistency of terms and confusion of definitions provided by researchers and practitioners with various backgrounds. In this chapter, we considered pervasiveness as a radial category – a categorization scheme based on design studies.

The chapter ends with an example on how the pervasive game features are present in *Pervasive Game Search*. Appendix C presents how the pervasive game features are present in the other prototypes.