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Chapter 10

Designing location-based mobile games: The *CityExplorer* case study

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> We authors, over the years, have felt many pangs of conscience as too much time is spent on games. (Peltola & Karsten, 2006, p. 6)

Introduction <<A Head>>

In writing this sentence, Peltola and Karsten (2006) express a widely shared feeling about game play. They go on, however, to make it clear that “playing in general is a necessary part of the experience of meaningful life (p. 6).” This statement is their summary of the opening chapter of the book *Homo Ludens* by Huizinga (1971). Huizinga identified several formal characteristics of games, one of which is spatial confinement, which games share with magic rituals that are bound to a “magic circle.” Huizinga argues that games and play are explicitly defined by the space within which they take place, the time a game or play lasts, and the rules that are active during the game/play. Participants of a game must freely agree to these changes in their ordinary life to be part of the game or play.

Location-based mobile games (LBMGs) break this traditional definition of games or play by extending their game play geographically, temporally, and socially (Montola, 2005). Montola (2005) states that these games—played with mobile devices that use some kind of localization technology, such as a GPS—relocate the game play from the static screen into the real world (geographic extension). Game play, therefore, interweaves (relatively uncontrolled) with everyday life activities, which makes it difficult not only for the players but also for possible bystanders (social extension) to differentiate between game and non-game phases (temporal extension). With such promising and manifold possibilities for designing totally new gaming experiences, it is not surprising that the design challenges of these games are only partly understood.

This chapter aims at improving the understanding of how to design LBMGs and overcome some of the basic challenges related to their design. In order to do that, we first present (in section 1) an overview of five known design challenges—*dealing with uncertainty, hybrid architectures, hefting domains, configuration,* and *orchestration* (Benford et al., 2005)—and two new design challenges—*geographic separation of players* and *the integration of non-gaming tasks*. Next, we illustrate possible solutions (section 2) by describing the design process of the LBMG *CityExplorer* in detail. In section 2, we will focus solely on the game design aspects of location-based games and will not explore in detail technological aspects such as software frameworks, localization technologies, or similar topics (see Paelke et al., 2008; Greenhalgh et al., 2007 or Rashid et al., 2006 on these topics). Then in section 3, we describe the design and execution of several case studies of *CityExplorer* in the city of Bamberg (Germany) and Fujisawa (Japan). After presenting and discussing the results of these studies, we finally give an outlook on further research directions in the area of LBMGs (section 4).

Section 1: Challenges of LBMG Design **<<A Head>>** Benford et al. (2005) define five challenges to the design of pervasive games that also hold true for LBMGs: *Dealing with uncertainty, hybrid architectures, hefting domains, configuration,* and *orchestration*.

(1) Dealing with uncertainty: *All localization technologies that can be used in location-based mobile games come with some kind of error attached to them. Such errors or uncertainties can be related first to the coverage (i.e., if the location technology is not available at all in the game area) or to some kind of jitter in the positional accuracy. Also, such errors can be related to the precision, that is, the position of players cannot be taken as certain for a given game situation.*

Benford et al. (2006) propose five possible solutions for dealing with uncertainty in game play terms: Remove, hide, manage, reveal, or exploit them. Drozed et al. (2006) even suggest using these strategies to deal with any seam that may surface when designing an LBMG. A seam in general is any kind of error in a computer system that hinders a seamless interaction of a user with the system. Following the thoughts of Mark Weiser (1999), one would conclude that a system without noticeable seams has the potential to be invisible to the user. This way the user can concentrate solely on his task at hand and not on the system. In a gaming context, this task is the immersion of the player in the game.

A location-based game designer can remove seams through different approaches. The most obvious one is to use advanced technology available, such as the latest GPS chip. Another way is to use algorithmic solutions to counter possible errors in the localization technology.

To hide seams, game designers must carefully design the user interface of the LBMG, so that the most likely errors are not obvious to the player. One might, for instance, choose a thematic map instead of a satellite image. This way, players will probably notice errors much less frequently. Because a thematic map is already an abstract representation of the real world, only rough errors in the positioning on such a map will be visible to the player. Another option is for the game to notify the player that a particular game location (i.e., room or space) has been entered without revealing its exact location or shape. In the Typhoon game (Oppermann et al., 2006), locations are identified by GSM cell-ids but the exact shapes of these cells is not shown to players, who know only whether or not they are inside a given GSM cell. Therefore, the fact that the spatial dimension of these cells can change over time is hidden.

Another strategy is to manage emerging seams. For example, the game design takes into account that for some regions of the game area no GPS signal can be received. In general, we can state that managing seams in this way always involves some kind of fall back to a low-tech but reliable solution. Instead of using GPS as a localization technology, one could use some sort of self-positioning methods (Nova et al., 2005; Benford et al., 2004a). A more expensive solution in organizational terms is to have various people in real-time monitor the game and solve problems manually.

A game designer can also choose to reveal all occurring seams in a game. Consequently, this lets the player decide how to handle errors during the game. A simple solution presented in Benford et al. (2006) is to visualize the error in some way. In *Can You See Me Now?,* for instance, the position of players is not represented by dot-like symbols, but rather with shapes that change according to the current accuracy of the used localization method, so that players can get a feeling of where and how strongly their game play is affected by a seam and develop strategies to counter or use it. Additionally, they provide a colored overview map in which every color stands for an accuracy level.

Another method is to exploit seams by designing the game experience explicitly around them. Chalmers et al. (2005) do not use predefined game locations in their game *Treasure* but randomly distribute the virtual game objects in the area, taking into account that some of them cannot be acquired by the players. Such game design is known in literature as *seamful design* (Barkhuus et al., 2005; Broll & Benford, 2005).

(2) Hybrid architectures: *The underlying architecture of LBMGs can be realized as client-server, peer-to-peer architectures, or as some combination of the two. Although this challenge primarily affects the technical realization of LBMGs, it is important in game design terms as well.*

Connected with the question of which architecture is best suited for an individual LBMG is the answer to whether the game features synchronous or asynchronous game play—or maybe even both. We say that game play is synchronous if it fulfills two constraints: (1) all participants play simultaneously, and (2) all game actions are immediately communicated to all affected players. We can say that all event-based LBMGs (Paelke et al., 2008) such as *Can You See Me Now?* (Benford et al., 2006), *Human Pacman* (Cheok et al., 2004), *PAC-LAN* (Rashid et al., 2006), *Uncle Roy All Around You* (Benford et al., 2004b), or *CityPoker* (Kiefer et al., 2007a) feature synchronous game play. However, open-world LBMGs—which are games where the game play can theoretically last infinitely long, such as *Botfighters* (Sotomaa, 2002), *Alien Revolt* (de Souza e Silva, 2008), or *Songs of North*[i] (Lankoski et al., 2004)—can feature asynchronous game play too.

Recently, asynchronous game play for LBMGs has come into the focus of research (Flintham et al., 2007). The main idea is to provide players the possibility to play the game temporally separated by using some kind of intermediate layer (typically a server that hosts the virtual game layer). Game actions are, therefore, not communicated directly to all affected players but to the intermediate layer that notifies the other players when they enter the game. This layer can be established not only by such simple means as having an online scoring board, as in *Feeding Yoshi* (Bell et al., 2006), but also by more complex ones, such as providing a game community web site, as in the *Gopher Game* (Casey et al., 2007) or *MobiMissions* (Grant et al., 2007).

(3) Hefting domains: *Which game elements are real objects and which are only virtually represented in an LBMG?*

To our knowledge this interesting challenge has not been subject to systematic research so far. Indeed only a few LBMGs explicitly use non-virtual objects in their game play. The geogame *CityPoker* (Kiefer et al., 2007a), for example, is played with real poker cards hidden in the game area. In *CityPoker,* two teams try to improve their starting poker hand of five cards by changing one card each time at five predefined locations. Whoever has the best poker hand after these five changes wins the game. Another example is *Insectopia* (Peitz et al., 2007), where any Bluetooth-enabled electronic device can function as a relevant game object. Problems such as theft prevent the usage of real-world objects in a citywide game area in a large scope, but an initial analysis from Choek et al. (2004) reports that an increase in the game experience of the players can be achieved by using real objects. In their *Human Pacman* case study with 23 players, 78.3%

of them stated that having "graspable interaction offered by the collection of real objects enhances the game (p. 80)." In *Human Pacman,* the special invincibility cookies that Pacman eats were represented as physical treasure boxes with an embedded Bluetooth device attached.

> (4) Configuration**:** *Configuration covers the problem of how to set up an LBMG in a real-world environment and how it can be relocated to another region on the earth.*
>
> (5) Orchestration: *Orchestration includes the problem of how an LBMG is best carried out, that is, how to organize "the real time management of a live game from behind the scenes."*

For both challenges, only game-specific solutions can be found in the literature. For example, in *Epidemic Menace* (Lindt et al., 2007), live actors and real-time monitoring of all game actions are used to orchestrate the game play. And although tool sets for live monitoring are indeed common (Crabtree et al., 2004 or Oppermann et al., 2006), so far no general framework has been proposed in this context. The same is true for the configuration of LBMGs.

Beside these five classic LBMG design challenges, we propose two additional challenges that our own research in this field has revealed and were only briefly sketched in the literature so far:

> (6) Geographic separation of players**:** *Playing an LBMG in a specific city can be quite entertaining, but what happens if one cannot find enough players willing to play the game? Can I play against a friend in another city? This challenge looks at the connection between geographically distributed players who nevertheless want to play an LBMG against each other. How can we overcome this geographic separation of players?*

Kiefer et al. (2007c) state that the crucial part in this challenge is to identify how players can trigger game actions in the game area. They distinguish between game areas where game actions can be triggered only on predefined game locations (spatially discrete) and game areas where the trigger can work anywhere in the game area (spatially continuous). Further they identify three sources of heterogeneity that have to be taken into account by a game designer: the spatial scale of the game area, the static structure (e.g., road network), and the dynamic conditions (such as the weather or traffic). If these sources are not addressed, especially in games that feature predefined game areas such as *CityPoker* (Kiefer et al., 2007c), an LBMG will be judged as being unfair. For example, if the distances in a road network (static structure) of a game area in city A are longer than that of the game area of the opposing players in city B and the game relies on speed, the players in city A will lay the blame on this circumstance when they lose. The same is true when game area A is much larger than game area B, so respectively more ground has to be covered in area A before a game action can be triggered. The dynamic conditions are only slightly controllable through game elements. For the most part, when a game takes place between A and B, a game designer can only hope that in both game areas the weather conditions are more or less the same. Nevertheless, we will see in section 2.2 how the shift from synchronous game play to asynchronous game play can be one solution to overcome this third source of heterogeneity.

(7) Integrating non-gaming tasks: *All LBMGs must cope with some kind of constraint that influences their design process. These constraints can be of an environmental nature (having to deal with an uncommon game area) or of special design goals (motivating the players to collect non-gaming data).*

Kiefer et al. (2007b) and Chen and Benford (2007) design LBMGs under the assumption that the players' primary goal is to get from point A to point B, and that playing is only a secondary goal. Players might be on a bicycle trip or a hitchhike; however, they are not willing or able to leave a predefined track. Bichard et al. (2006) restrict the play even more. They design games for players sitting in the backs of cars. Besides offering game-related solutions, Kiefer et al. (2007c) suggest using methods such as space-filling curves (Güting, 1994) to first linearize game locations found in an arbitrary two-dimensional game area to preserve the neighborhood relations as effectively as possible. As a second step, the now one-dimensional game area has to be consecutively mapped to the route the players want to take. Kiefer et al. (2007c) use the already linear game *Alak* (first mentioned in Dewdney, 1984), a linear version of Go, as an example. Depending on the total length of the route the players want to take, the linear game board is repeated "n" times along their route, so that players do not have to turn around to reach a game board location that they have already past. Instead they can just move to the next game board that represents the exact same game state as the previous one. With the simulation framework from Kiefer et al. (2007c) one can compute how many times the game board has to be repeated, which results in an exciting game.

Quite another design goal is the one Matyas (2007) investigates: designing LBMGs to gather geospatial data. In his work, he proposes three game design patterns that enable the integration of data acquisition tasks into an LBMG—the *transportation*, *exploration,* and *quest* patterns. Wolff and Grüter (2008) took this idea even one step further by looking at the LBMG player as a general content producer, not only of game-related content outside of the game but also of the game itself—like new missions or virtual items. This evolution is similar to the evolution observed in PC and console games, where players were eventually encouraged to also create in-game content. *CityExplorer,* which belongs to the class of LBMGs called geogames (Schlieder et al., 2006), was first introduced by Matyas (2007) as a theoretical design example. In the next section, we explore how this theoretic example is turned into a working game, addressing the afore-mentioned challenges.

Section 2: The Geogame *CityExplorer*—Seamful, Asynchronous, and Multi-city Game Play <<A Head>>

The geogames framework presented in Schlieder et al. (2006) has been designed to systematically explore how the physical challenges (locomotion) of an LBMG interact with the strategic elements (reasoning), and how each contributes to the game playing experience. This framework enables a game designer to turn almost any classical board game or card game—together with its specific form of strategic reasoning—into an LBMG.

Section 2.1: General game design idea <<B Head>>

CityExplorer was inspired by the award-winning board game *Carcassonne*, originally designed by Klaus-Jürgen Wrede. A game of *Carcassonne* always starts with a single tile of the fragmented and hidden game board. Players take turns to draw a new tile and lay it down to extend the land of *Carcassonne*. Then, they have the choice to place one of their game markers (followers) on the tile just dropped. Followers can be placed on the locations of only specific object categories—for example, on churches—to control them. A player gets credits for the objects their followers hold under control. Once all tiles are laid down, the final scoring takes place. The player with the highest score wins.

For *CityExplorer,* we adopt these main game ideas and relocate the game play in the real world via mobile devices coupled with GPS technology and a corresponding website. Therefore, the game consists of an online and an offline (mobile) component. We will now look into those game play elements that are a direct reaction to the challenges discussed in section 1.

Section 2.2: Resolving design challenges <<B Head>>

The primary way to win a game of *CityExplorer* is to set as many markers as possible in a (typically) citywide game area. To mimic the tile-based game play of the original, the game area is further divided into non-overlapping squares (see Figure 1). In each of these squares, the setting of markers is allowed, but only on predefined categories of locations, such as churches or restaurants. In short, the main game rules of *CityExplorer* are as follows: Players explore the segmented game area and place their markers on valid locations within them. The player who holds the majority of markers in such a region claims the domination of it and gets points for it at the end of the game. Additionally, players get points for placing the most markers to one type of valid locations on the entire game board. Consequently, in order to win the game, the player must keep in mind not only the marker count in the different game board segments but

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also which player is currently leading a location category. When the game time (which can range from a few days to several months) is over, the player who has gathered the most credits wins. For a detailed description of the game rules, please refer to the *CityExplorer* website (http://www.kinf.wiai.uni-bamberg.de/cityexplorer).

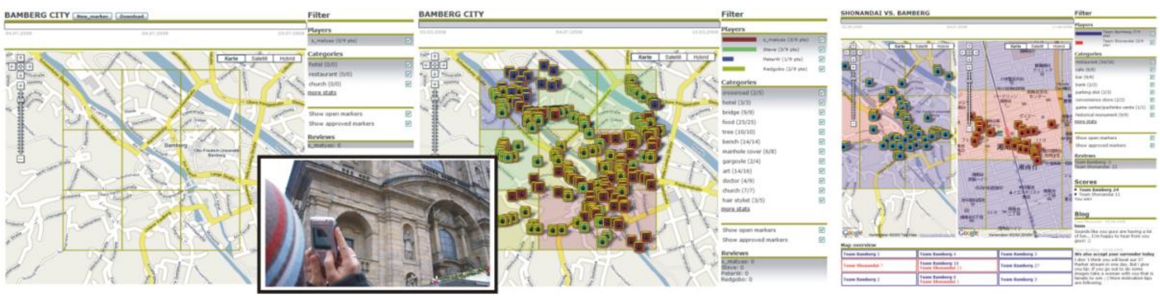

Figure 1: Single-city game and multi-city game of *CityExplorer*, played in Bamberg and Fujisawa (map images © Google Maps).

To make the set up and relocation of the game (configuration challenge) as easy as possible and to increase the replay value, an equal number of categories is chosen by each player of a *CityExplorer* game before a game round starts. No categories are predefined by the game so that players have to come up with whichever location categories they know of, resulting in more general categories such as “food” or “art,” or very precise categories such as “bar” or “café,” so that different knowledge levels of players are balanced (orchestration challenge).

As *CityExplorer* implements the *exploration* pattern (Matyas, 2007), the game starts with a completely empty game board without any predefined game locations, so that every real-world location of a chosen game category can be turned into a game location (hefting domain challenge). This seamful design approach also makes games between geographically separated players—we call multi-city game play—easily possible. In this manner, only the spatial scale is of importance when matching the separated game areas (geographic separation challenge).

As *CityExplorer* is especially designed to enable the collection of geospatial data (Matyas, 2007), the setting of a marker involves the following steps (integrating non-gaming tasks challenge): (1) take a photo of the location you want to set your marker at, (2) type in the name of the location, (3) walk as near to the location as possible, and (4) select the correct location category. At step (1) and (4)—taking a photo and the categorization of the location—the current GPS coordinate is taken. With these two GPS coordinates, the angle from which the photo for the marker was taken can later be reconstructed. All of these gathered geospatial data can later be used in other contexts, such as community-based location-based services (Bellavista et al., 2008).

Having recorded a considerable number of markers, the player copies her photos and metadata (recorded in an XML-file) from the mobile phone to a computer and uploads the marker collection to the *CityExplorer* web site. With this indirect upload approach, players do not need a mobile data flat rate to enjoy the game. We also do not have to handle errors in the underlying communication network (orchestration challenge).

The online component of the game gives us the possibility to also develop asynchronous game play (hybrid architectures challenge). Players do not need to play the game at the same time but can play the game (mobile and online) whenever they have time slots left in their everyday schedule. Nevertheless, they always have the possibility to check the status of their game on the web site. Additionally, they can play some parts of the game when, for example, the weather is not adequate for playing (geographic separation challenge).

Because the game software cannot check if an uploaded marker is correct—the location, photo, tag, and the chosen category—we implemented a community-driven review process for *CityExplorer* (dealing with uncertainty challenge).

All players judge the correctness of all other players' markers anonymously. In our current build of the game, a player can either approve or refuse a marker of another player. A player is not allowed to approve or refuse his own markers. If the marker is approved, it is set to be correct and cannot be refused by another player. If the marker is refused, the owner of the marker has a single opportunity to correct whatever the reviewer said was incorrect. After such a correction is made by the owner, the marker must be reviewed by a player in the game other than the initial reviewer. If the marker fails this second review too, it does not count for the game. This way every marker is reviewed by at most two different players. The reviewing process in its current form serves two purposes: it counters (1) uploading of incorrect markers in great numbers and (2) the unjust or random refusing of markers. To motivate the players to review markers at all, the player with the most reviews gets a predefined amount of credits at the end of the game (orchestration challenge).

Section 3: Case Studies—Exploring the City <<A Head>>

To evaluate the approaches used in the design of *CityExplorer* to handle the design challenges introduced in section 1, several case studies were carried out in the city of Bamberg (Germany) and Fujisawa (near Shonandai station, Japan). Overall three games were played in Bamberg. In one additional game, a team in Bamberg competed against a team in Fujisawa in a multi-city game.

Section 3.1: Single-city games <<B Head>>

A total of 14 players participated in the three games in Bamberg—four in the first (all computer science students), six in the second (four computer science and two cultural science students), and four in the third (all computer science students). The players' ages ranged from 21 to 32. All of the participants had some kind of knowledge about the GPS technology, varying from "heard of" to "was having a lecture about it" to "expert knowledge." Three different time intervals (seven, nine, and four days) were chosen for the games to evaluate how the usage of hybrid architecture (client-server) can facilitate asynchronous game play in different time intervals, from more event-based to open-world. Twelve of the participants completed a questionnaire and participated in a short question-and-answer round after each game.

The overall reactions of the players were positive, and the mobile photo taking part of the game was especially perceived as very encouraging and entertaining; 10 out of 12 players would like to play the game at least a second time. In the following section, we will discuss the player's reactions in more detail.

Section 3.2: Multi-city game <<B Head>>

In the *CityExplorer* game between the city of Bamberg and the city of Fujisawa (near Shonandai station, Japan), two teams, each with four participants, competed against each other. The game time was set to four days. The game area for both teams was located in their respective cities as can be seen in Figure 1. The overlaid virtual game board segments were mapped on each other by the game logics; so if a player set a marker in Bamberg in the upper left segment, it counted also as a marker for the upper left segment on the game board in Fujisawa. Furthermore, the same location categories were used for both game areas.

From work by Kiefer et al. (2007c), we know that, for location-based games with no predefined game-relevant locations, only the physical spatial scale of the two game boards has to be matched. For our multi-city game case study, we chose an appropriate area of approximately 4 km^2.

Unfortunately, the orchestration costs in the context of a geographic separation of players increase for a *CityExplorer* game with geographically separated teams, because players of one team cannot judge the correctness of markers from the team in the other city. So, for this particular setup, we assigned neutral reviewers for each game area. Please note that this is necessary only when two teams compete against each other. If the players from the two cities were to play on their own, the review process would be conducted as in a single-city game. Theoretically, the *CityExplorer* web site enables the connection of n game boards. Our design decision for asynchronous game play (hybrid architectures challenge) in *CityExplorer* resolved the problem of inter-network communication between Germany and Japan that would have been imminent if we had strove for a synchronous game play. Additionally, we did not use the J2ME client from the single-city games in Bamberg. Although we had successfully redeveloped and tested a version for Japanese mobile phones (DoCoMos DoJa 5.0) in the city center of Yokohama, we wanted to come up with a more design-oriented solution. Our design solution is applicable to really every region in the world without further redevelopment of our mobile software (configuration challenge), which we see as the most expensive part in the development of mobile applications in general, mainly due to the huge platform diversity of mobile phones available (Greenhalgh et al., 2007).

So, for *CityExplorer* games of geographically distributed players, we use the low-tech method of self-positioning, known from work done by, for example, Nova et al. (2005) and Benford et al. (2004a). In games that feature this technique, players position themselves manually via a map interface and do not use automatic localization technologies such as GPS. As a consequence, to take part in a *CityExplorer* game that uses self-positioning, I need only a mobile device with a camera. The marker setting process was, therefore, altered in the following way: (1) take a photo of the location with at least one team member visible (which ensures that the photo originates from the game and is not taken from any other source, such as a photo database on the web) and (2) upload all photos through a special web interface to the *CityExplorer* web site. With this web interface, all remaining metadata for a marker (position of photographer, position of the photographed location/object, the location category, and the location name) must be selected or typed in manually. This way the game is relocated to other game areas in an even easier way (configuration and geographic separation challenge).

Three of the four Japanese players (all Keio University students with different academic concentrations) also completed a questionnaire. In this game, the age of the players ranged between 20 and 21 and none of the participants had any previous experience with GPS. Because their counterpart participants in Bamberg had already completed a questionnaire, they participated only in a question-and-answer session for this game.

Section 3.3: Discussion <<B Head>>

The 14 players in Bamberg collected a total of 771 markers over a period of 20 days: 276 in the first, 308 in the second, and 187 in the third game. Based on participant responses to the prompt "The outdoor part of the game was fun to play" and the number of markers players collected, we believe our design decisions for the mobile part of the game are successful in dealing with the design challenges orchestration, dealing with uncertainty, and integrating non-gaming tasks.

Unfortunately, the online part of *CityExplorer* was not perceived as being as entertaining as the mobile part (hybrid architectures challenge). The question-and-answer sessions revealed that the uploading and reviewing steps were seen as a little cumbersome. Here, a redesign of the web interface was suggested by the players to make it smoother to use, for example, to have the possibility to review multiple markers simultaneously. However, the fact that the online reviewing was an integrated part of the game through which credits could be earned motivated the participants enough to do it at least to some extent. Our data shows that players of all four case studies reviewed 39% of all uploaded markers. For a more detailed evaluation of the geographic data (integrating non-gaming task challenge) collected through *CityExplorer,* see Matyas et al. (2008).

For the upload problem, the players suggested we integrate an alternative direct upload mode, so that the players could add their marker to the game server on the move. But they agreed that the cost (GPRS/UMTS connection price) of such a solution would decrease the overall appeal of the game if there are no affordable flat rate models available in the country the game is played.

Due to the manual upload process in the geographically separated game (and the strict time restrictions), "only" 106 markers were collected in the geographically distributed game. From participants' questionnaire responses and question-and-answer participation, we believe that the distributed game play is possible and potentially as immersive as the single-city game. By using a seamful design approach such as *CityExplorer,* the configuration and geographic separation challenges can be solved.

Furthermore, other responses to the questionnaire indicated that the game encouraged the players to spend more time outdoors than they usually would, and that they visited places they rarely do (integrating non-gaming task challenge). This strengthens results reported by Anderson et al. (2007) that mobile technology can stimulate people to be more physically active. Their mobile phone application *Shakra* interprets patterns of fluctuation in GSM signal strength as different activities of the user, such as walking or driving, and gives him a report of his activities throughout the day. According to Anderson et al., these reports alone encourage the users to be more physically active.

Another common theme in the question-and-answer sessions was the changing sense of the real-world environment through playing the game (hefting domain challenge). All players mentioned that while playing the *CityExplorer* their perception of the city space increased. For example, in our first game in Bamberg, players chose the category "hair stylist." Two players reported that before the game they knew only of one or two hair stylists in the city center of Bamberg, but while playing, they suddenly noticed a hair stylist on every next street corner.

Section 4: Outlook <<A Head>>

In this chapter, we have presented seven design challenges that a designer of LBMGs has to be aware of, five of which were earlier noted by Benford et al. (2005). We pointed out several known solutions found in the literature and our own research and further illustrated them by describing the design of the geogame *CityExplorer* in detail. Several case studies show that our game design decisions result in a compelling game experience and can, therefore, provide some advices for other LBMG designers as well.

In the design of *CityExplorer,* we did not consider one further challenge we nevertheless find worth mentioning: The challenge of modeling an intelligent and entertaining AI opponent for LBMG. There exists a rich body of work on AI modeling for PC or video games (Rabin, 2002), but to our knowledge only one particular work investigated the question of how an AI opponent has to be modeled for a location-based game: the 2005 publication of Kiefer et al., in which the authors conclude that AI opponents for LBMG should preferably mimic real, live opponents because the motivation to play against a virtual opponent on the streets is even less than one might have while sitting relaxed on a sofa at home. However, because their work is only of theoretical nature, and because early evaluations of working LBMGs such as *Alien Revolt* (de Souza e Silva, 2008) have challenged their conclusions, more detailed research is clearly necessary on this particular subject. We hope that the presented design challenges for LBMG, although by no means complete, are seen as an initial framework of design guidelines that future game designers take into account when building their next LBMGs.

Acknowledgements <<A Head>>

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References <<A Head>>

Anderson, I., Maitland, J., Sherwood, S., Barkhuus, L., Chalmers, M., Hall, M., Brown, B., & Muller, H. (2007). Shakra: Tracking and sharing daily activity levels with unaugmented mobile phones. *Mob. Netw. Appl.* 12, 2–3 (Mar. 2007), 185–199.

Barkhuus, L., Chalmers, M., Tennent, P., Hall, M., Bell, M., Sherwood, S., & et al. (2005). Picking pockets on the lawn: The development of tactics and strategies in a mobile game. UbiComp 2005, Springer, LNCS 3660, 358–374

Bell, M., Chalmers, M., Barkhuus, L., Hall, M., Sherwood, S., Tennent, P., & et al. (2006). Interweaving mobile games with everyday life, SIGCHI Conference on Human Factors in Computing Systems, CHI '06, ACM Press, New York, NY, 417–426

Bellavista, P., Küpper A., & Helal, S. (2008). Location-Based services: Back to the future, IEEE Pervasive Computing, vol. 7, no. 2, Apr.–Jun. 2008, pp. 85–89

Benford, S., Seagar, W., Flintham, M., Anastasi, R., Rowland, D., Humble, J., & et al. (2004a), The error of our ways: The experience of self-reported position in a location-based game, Ubicomp 2004, Springer LNCS 3205/2004, 70–87

Benford, S., Flintham, M., Drozd, A., Anastasi, R., Rowland, D., Tandavanitj, N., & et al. (2004b), *Uncle Roy All Around You*: Implicating the city in a location-based performance, advances in computer entertainment technology, ACE 2004, Jun. 2004, ACM.

Benford, S., Magerkurth, C., & Ljungstrand, P. (2005). Bridging the physical and digital in pervasive gaming, Commun. ACM, vol. 48, no. 3, Mar. 2005, 54–57

Benford, S., Crabtree, A., Flintham, M., Drozd, A., Anastasi, R., Paxton, M., & et al.

(2006). Can you see me now?, ACM Trans. Comput.-Hum. Interact, vol. 13, no. 1, Mar. 2006, 100–133

Bichard, J., Brunnberg, L., Combetto, M., Gustafsson, A., & Juhlin, O. (2006). Backseat playgrounds: Pervasive storytelling in vast location-based games. International Conference on Entertainment Computing—ICEC 2006. Springer Verlag, 117–122.

Broll, G., & Benford, S. (2005). Seamful design for location-based mobile games, International Conference on Entertainment Computing (ICEC), Osaka, Japan, Sept. 19–21, 2005.

Casey, S., Kirman, B., & Rowland, D. (2007). The gopher game: A social, mobile, locative game with user generated content and peer review. Advances in Computer Entertainment Technology. ACE '07, vol. 203. ACM, New York, NY, 9–16

Chalmers, M., Bell, M., Brown, B., Hall, M., Sherwood, S., & Tennent, P. (2005). Gaming on the edge: Using seams in ubicomp games. ACM SIGCHI Advances in Computer Entertainment Technology, ACE '05, vol. 265. ACM, New York, NY, 306–309

Chen, L., & Benford, S. (2007). Your way your missions: From location-based to route-based pervasive gaming. Advances in Computer Entertainment Technology, ACE '07, vol. 203. ACM, New York, NY, 232–233

Cheok, A., Goh, K. H., Liu, W., Farbiz, F., Fong, S. W., Teo, S. L., Li, Y., & Yang, X.. (2004). Human Pacman: A mobile, wide-area entertainment system based on physical, social, and ubiquitous computing. Personal Ubiquitous Comput. 8, 2

(May 2004), 71–81

Crabtree, A., Benford, S., Rodden, T., Greenhalgh, C., Flintham, M., Anastasi, R., Drozd, A., Adams, M., Row-Farr, J., Tandavanitj, N., & Steed, A. (2004). Orchestrating a mixed reality game 'on the ground'. SIGCHI Conference on Human Factors in Computing Systems. CHI '04. ACM, New York, NY, 391–398

de Souza e Silva, A. (2008). Alien-Revolt: A case study of the first location-based mobile game in Brazil. *IEEE Technology and Society Magazine,* 27 (1), 18–28.

Dewdney, A. K. (1984). The Planiverse—Computer contact with a two-dimensional world, Simon & Schuster, ISBN 0-671-46362-4

Drozd, A., Benford, S., Tandavanitj, N., Wright, M., & Chamberlain, A. (2006). Hitchers: Designing for cellular positioning, Ubicomp, Springer LNCS, vol. 4206, 279–296

Flintham, M., Smith, K., Benford, S., Capra, M., Green, J., Greenhalgh, C., Wright, M., Adams, M., Tandavanitj, N., Row Farr, J., & Lindt, I. (2007). Day of the figurines: A slow narrative-driven game for mobile phones using text messaging, Symposium on Pervasive Gaming Applications (PerGames 2007), Shaker Verlag Aachen 2007, ISBN 978-3-8322-6288-4

Grant, L., Daanen, H., Benford, S., Hampshire, A., Drozd, A., & Greenhalgh, C. (2007). MobiMissions: The game of missions for mobile phones. ACM SIGGRAPH 2007 Educators Program. SIGGRAPH '07. ACM, New York, NY, 12

Greenhalgh, C., Benford, S., Drozd, A., Flintham, M., Hampshire, A., Oppermann, L., Smith, K., & von Tycowicz, C. (2007). Addressing mobile phone diversity in Ubicomp experience Development, UbiComp 2007Springer, LNCS 4717, 447–

464

Güting, R. H. (1994). An introduction to spatial database systems. *The VLDB Journal* 3, 4 (Oct. 1994), 357–399.

Huizinga, J. (1971), Homo Ludens: A Study of the play-element in culture, Beacon Press, ISBN-10: 0807046817

Kiefer, P., Matyas, S., & Schlieder C. (2005). State space analysis as a tool in the design of a smart opponent for a location-based game, Computer Science and Magic 2005, GC Developer Conference Science Track, Aug.16–18, 2005, Leipzig, Germany, Messe Leipzig, ISBN 3-9804874-3-1

Kiefer, P. , Matyas, S., & Schlieder, C. (2007a), Geogames—integrating edutainment content in location-based games, in Carsten Magerkurth and Carsten Röcker (eds.), *Concepts and Technologies for Pervasive Games—A Reader for Pervasive Gaming Research* vol. 1, Shaker Verlag, Nov. 2007, ISBN: 978-3-8322-6223-5, pp. 127–152

Kiefer, P., Matyas, S., & Schlieder, C. (2007b). Playing on a line: Location-based games for linear trips. Advances in Computer Entertainment Technology. ACE '07, vol. 203. ACM, New York, NY, 250–251

Kiefer, P., Matyas, S., & Schlieder, C. (2007c). Playing location-based games on geographically distributed game boards, symposium on pervasive gaming applications (PerGames 2007), Shaker Verlag Aachen 2007, ISBN 978-3-8322-6288-4, pp. 63–71

Lankoski, P., Heliö, S., Nummela, J., Lahti, J., Mäyrä, F., & Ermi, L. (2004). A case study in pervasive game design: The songs of north. Nordic Conference on Human-Computer interaction. NordiCHI '04, vol. 82. ACM, New York, NY, 413–416

Lindt, I., Ohlenburg, J., Pankoke-babatz, U., & Ghellal, S. (2007). A report on the crossmedia game epidemic menace. Comput. Entertain. 5, 1 (Jan. 2007), 8

Matyas, S. (2007), Playful geospatial data acquisition by location-based gaming communities, *The International Journal of Virtual Realities* (IJVR) 6(3), 2007, www.ijvr.org, IPI Press, ISSN 1081–1451, 1–10

Matyas, S., Matyas, C., , Kiefer, P., Schlieder, C., Mitarai, H., & Kamata, M. (2008), Designing location-based mobile games with a purpose—collecting valuable goods with CityExplorer, In ACE 2008, Yokohama, Japan, 3–5 Dec., ACM proceedings

Montola, M. (2005). Exploring the edge of the magic circle. Defining pervasive games. DAC 2005 conference, Dec. 1–3. IT University of Copenhagen

Nova, N. Girardin, F., & Dillenbourg, P. (2005). 'Location is not enough!': An empirical study of location-awareness in mobile collaboration, IEEE International Workshop on Wireless and Mobile Technologies in Education(WMTE), ISBN: 0-7695-2385-4.

Oppermann, L., Broll, G., Capra, M., & Benford, S. (2006). Extending authoring tools for location-aware applications with an infrastructure visualization layer, Ubicomp 2006, Sept. 17–21, Orange County, CA, Springer, 2006.

Paelke, V., Oppermann, L., & Reimann, C. (2008). Mobile location-based gaming, In Meng, L., Zipf, A., & Winter, S. (eds.), *Map-based Mobile Services—Design,* *Interaction and Usability, Lecture Notes in Geoinformation and Cartography,* 2008, ISBN: 978-3-540-37109-0, pp. 310–332

Peitz, J., Saarenpää, H., & Björk, S. (2007). Insectopia: Exploring pervasive games through technology already pervasively available. Advances in Computer Entertainment Technology. ACE '07, vol. 203. ACM, New York, NY, 107–114

Peltola, J., & Karsten, H. (2006). When play is not enough: Towards actually useful applications for digital entertainment, Helsinki Mobility Roundtable 2006, Helsinki School of Economics, last accessed on the 16 Oct. 2008 at http://project.hkkk.fi/helsinkimobility/papers/Mobile%20Enterprise_3_2.pdf

Rabin, S. (2002), AI game programming wisdom, Thomson Learning, ISBN-13: 978-1584500773

Rashid, O., Bamford, W., Coulton, P., Edwards, R., & Scheible, J. (2006). PAC-LAN: Mixed-reality gaming with RFID-enabled mobile phones. Comput. Entertain. 4, 4 (Oct. 2006), 4.

Schlieder, C., Kiefer, P., & Matyas S. (2006). Geogames—designing location-based games from classic board games, IEEE Intelligent Systems, vol. 21, no. 5, Sept./Oct. 2006, pp. 40–46

Sotomaa, O. (2002). All the world's a Botfighter stage: Notes on location-based multi-user gaming. Tampere University Press, Tampere.

Weiser, M. (1999). The computer for the 21st century. *SIGMOBILE Mob. Comput. Commun. Rev.* 3, 3 (Jul. 1999), 3–11

Wolff, S., & Grüter, B. (2008). Context, emergent game play and the mobile gamer as producer, GI Jahrestagung 2008, GI-LNI 133, 495–500.

[i] Editors' note: See Mäyrä and Lankoski's chapter in this volume.