# Playful Geospatial Data Acquisition by Location-based Gaming Communities

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**Abstract.** The success of Web 2.0 communities demonstrates that the users of an information service are willing to participate in the content creation process on a voluntary basis. In this paper we adapt this idea to the task of collecting geographic data by player communities of location-based games. We identify three types of geographic data that players can collect as part of the game experience: (1) data about the localization/communication network, (2) data about the geographic environment, and (3) related non-geographic information. Furthermore, we present game design patterns that permit to gather all three types of data. The approach is illustrated with the Geogame "CityExplorer". First empirical results are reported from the evaluation of geographic data acquired over a one-year period with two Geogames, "GeoTicTacToe" and "CityPoker".

## 1 Introduction

The ongoing success of Web 2.0 applications and associated technologies (such as Wikis) shows that user communities are prepared to be involved in a voluntary content creation process. In this context the idea to collect spatial data by voluntary contributors emerged. Concerning the elevated price of spatial data sets and the unavailability of data meeting the needs of specific user groups, this is not surprising. The PARAMOUNT project (Loehnert et al. 2001), an early example, provides a location-based service for hikers. Not only predefined location-based content is shown to the hiker on their mobile device. They are also able to post their touring experiences in addition to their GPS track data. And these data can be shared with other hikers. Another example is the digital trail library described by Morris et al. (2004). In this work mountain biker builds a library of GPS track data. The tracks can be downloaded and used by others on their mobile devices for navigation purposes.

Such community-based approaches to geographic data collection are well suited to handle information needed and shared by small and non-commercial information communities. In contrast, the commercial providers of data sets, e.g. for car navigation systems, focus on their customers primary interests in car navigation. As a consequence, e.g. biking trails are not included in the data set despite the possibility.

A further strength of community-based collection of geographic data also lies in the ability to gather local knowledge. These little pieces of geo-referenced informa-


**Fig. 1.** Players of a location-based game and their GPS traces visualized on a topographic map of the city of Bamberg, Bavaria, Germany (1:25000)

tion are not of interest for a buying majority, but can bring a deeper meaning to the coordinate pair of a real world location. A name for a point of interest can be such a piece of geo-referenced information, or those sophisticated ones like a textual evaluation of a restaurant, see for example Espinoza et al. (2001) or Lane (2003).

To our opinion, the real challenge lies in motivating the user to provide the data constantly, even after the exciting appeal of technological innovation at the beginning wears off. The data acquisition process should be entertaining for a possible contributor to engage him in the long run. We convince that entertainment and fun are an important design aspect of such data collecting services.

Von Ahn et al. (2005) already used this aspect to motivate regular non-expert internet users to assign appropriate semantic labels to pictures found in the World Wide Web with success. They designed a cooperative two-player game, the ESP-Game. The Players get points for equal labels they associated to a given picture. These labels can then be used by e.g. Google Image Search for later retrieval requests from other users.

In our paper we adopt the idea of mixing an entertaining experience with a useful task, as Peltola et al. (2006) puts it: “game play is a natural motivator to participate in something that is not necessary or beneficial”. We fortify this statement by proposing to gather geographic data in a playful way. In particular, we created location-based games for data gathering purpose. For example figure 1 displays two highly motivated players and their collected GPS trace in the city of Bamberg (Bavaria, Germany), playing on of our location-based games.

In section two, we identify three types of geographic data that can be gathered by using location-based games in general. In this context we present representative location-based games found in the literature. In section three, we discuss game elements critical for the design of a playful location-based data acquisition und three design patterns that can be implemented in different location-based games. A design example, the Geogame (Schlieder et al. 2006) CityExplorer, illustrates the possibility to

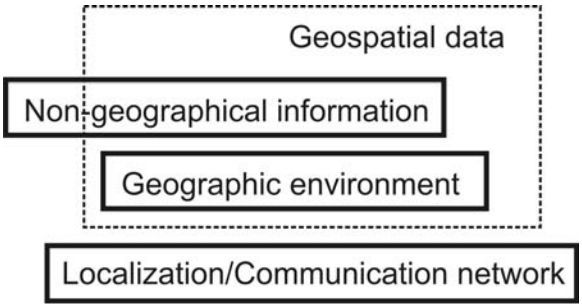


**Fig. 2.** Types of data possible to collect with location-based games

collect especially non-geographic information (section three) with a location-based game as well. To support the feasibility of our claim, section four evaluates geographic data sets collected over a one year period by playing two Geogames, GeoTicTacToe (Schlieder et al. 2006) and CityPoker (Kiefer et al. 2007). The last section summarizes our experience gained from the use case studies and points out future research areas.

## 2 Data Acquisition with Location-based Games

In the following we distinguish three types of geographic data that can be acquired using location-based games as a data collecting instrument. (See also figure 2):

*Localization/communication network*: Location-base games have to use some sort of localization technology, like GPS or positioning in WiFi or GSM networks, to pinpoint game relevant objects, including the players. The same technologies are also important for other non-gaming services as well, primarily for traditional location-based services. Gathering data about these localization networks, for example where good GPS signals can be received, can help building qualitative better non-gaming services. Although not necessary for all location-based games communication networks, e.g. GSM/GPRS or UMTS, are used to synchronize the global game state directly between players or indirectly through a game server. Therefore, data about these networks can be collected as well. Analysing where good network connections are available can be important e.g. for mobile TV service providers.

*Geographic environment*: Geographic data about real world objects, like roads or points of interest (e.g. restaurants or historical buildings) are especially interesting for location-based services. Such objects are frequently found in game areas of location-based games. Logging the GPS signal to retrieve GPS traces of road segments during the course of a location-based game would be an example to collect data about the geographic environment.

*Non-geographical information*: In principle all types of information falls in this class. But information belonging to real world objects found in the geographic environment present the basis for all location-based services, like a yellow page service or a tourist guide. Therefore, we subsume under the term *geospatial data* data about the geographic environment and directly associated non-geographic information. Classifications of POI, ratings of a specific restaurant or opening times of a concrete museum are common examples. We will discuss in section 4 how to incorporate tasks into location-based games to gather these kinds of geographic data.

Especially local knowledge is most valuable for non-gaming location-based services, like the shortest path for a tourist on foot from one sightseeing point to another. Another example would be locations of hotels with a good price-performance ratio. Such data can be gathered by commercial organizations only at high cost. If well integrated in a location-based game, players will willingly gather such geospatial information as part of the game play, because they want to win the game. The data acquisition possibility is therefore only limited by an appropriate design of the location-based game.

However, so far to our knowledge, location-based games in the literature concentrate solely on gathering data about the localization/communication networks, neglecting the more meaningful geospatial data. The following games are the most prominent examples.

*Treasure* (see Chalmers et al. 2004 and Barkhuus et al. 2005) is used to build WiFi coverage maps of a given game area. Players pick up virtual coins scattered over the game area and then put them into a virtual chest by connecting to a server. The chance to load up the found coins is higher with a better network connection, so that players are encouraged to search for areas with good WiFi coverage.

Bell et al. (2006) present a simple game called *Feeding Yoshi!*. Teams of players search for open and close WiFi hotspots in order to harvest virtual fruits (close hotspots) and feed them to virtual pets called Yoshis (open hotspots).

In *Tycoon*, designed by Broll and Benford (2005), players compete to gain the largest amount of credits by buying virtual objects, e.g. buildings or estates, in a predefined game area. Resources in the game (gold, silver and copper) can be collected on locations (gold, silver and copper mines) mapped to the real world by GSM cell-ids. On separate locations (brokers) the collected resources can be exchanged for the game relevant objects to earn the most credits. By using the cell-id and GPS traces the spatial coverage of a GSM cell is evaluated.

The game *Hitchers* from Drozd et al. (2006) enables players to expose virtual ghosts in the real world with the mission to travel to a given real world location, identified by GSM cell-id. Other players are able to pick up ghosts in a cell and carry them to their destination. Logs of the travel routes of the ghosts are used to build GSM cell-id maps.

Benford et al. (2006) use game logs from their game *Can You See Me Now?* to create GPS and WiFi coverage maps. The collected data are then used to reconfigure the game, avoiding using real world areas in the next game event with bad localization and communication network coverage.

Most of the above mentioned geographic data are already collected by experts of private or governmental contributors too (e.g. Navteq or a state office for survey and geographic information in the federal states of Germany). But data collections by location-based gaming communities contain two benefits, besides from being free of charge.

First, given a broad spreading of this kind of gaming, their databases will be continuously updated by the community whenever a game event takes place. With a strong community these updates could be accomplished even more frequent than from expert organizations. According to Gösseln and Sester (2003) the update period of the digital topographic data set (ATKIS) from state office for survey and geographic information in the federal states of Germany ranges from three month for important data to one year. ATKIS includes data about the geographic environment (especially road network data), with some non-geographic information like names for cities, for Germany. On this basis topographic maps of different scale (e.g. 1:25000) are constructed (see Figure 1). Although this is handled different around the world the state office for survey and geographic information for Bavaria for example updates their topographic maps just every four to five years[1]. This update period could clearly be shortened when using location-based game, as we will discuss in more detail in section 4.

Second, location-based games can be conducted wherever an adequate localization network is available, which in the case of GPS is actually everywhere on the planet. Particularly data about places that are not of interest for a paying majority, like rural areas with spare settlement and some minor roads but with a rich network of biking trails. All of this data can be acquired through appropriate designed location-based games. ATKIS in contrast, only covers road network data for cars but not for bikers.

## 3 Designing a Playful Data Acquisition

The most critical part of integrating a serious aspect into the fun and entertainment of location-based games or games in general is how to balance these two sides equally (Gunter et al. 2006). Concerning the design of a location-based game with data acquisition intention, the handling of non-geographical information must be particularly carefully treated by the game designer. Since location-based games always use some localization/communication networks and take place in the real world, like discussed in section two, the other two types of data can be acquired more easily.

Regarding Konzacks (2002) seven layer structure of a (computer) game we restrict ourselves in the rest of the paper to examine elements on the game play layer. The game play elements found there can then be easily augmented with manifold variants of thematic themes and/or storylines to create desired gaming experiences.

[1] www.geodaten.bayern.de

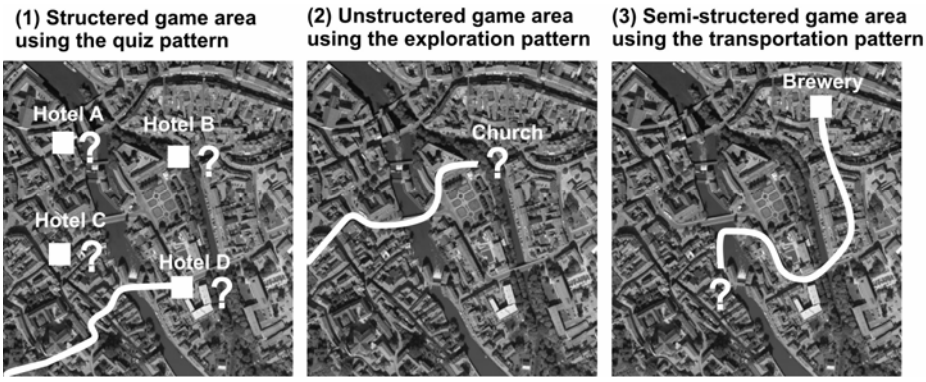


**Fig. 3.** Potential implementations of the proposed game design patterns on different structured game areas

### 3.1 Network and Geographic Environment Data Collections

Any location-based game must use some kind of localization network to keep track of the players and/or game objects movement respectively positions in a given game area. In most of the cases, a communication network to synchronize game states between players is also needed. Due to these two facts corresponding data about these networks can be collected alongside the actual game play without the need to implement any special game elements into the game.

Nearly the same holds true, regarding data about the geographic environment. Each type of location-based game is well suited to collect coordinate pairs within the game area, using a localization network. In order to collect these environmental data more systematically, a closer look should be taken at the structure of the game area, or the game's *space* (Konzacks, 2002).

The systemization of Kiefer et al. (2006a) helps here. The authors suggest location-based games can be differentiated by the fact where exactly gaming actions occur in a predefined game area. In spatially continuous games, gaming action can be carried out everywhere in the game area, in spatially discrete games, only on fixed spots. Mixed forms are also possible.

Each of these three game types can be preferable, depending on the kind of game a game designer wants to create or the type of geographic data he wants to collect with it. Nevertheless, our experience shows that fixed game-relevant locations are kind of able to "force" the players to collect data about the geographic environment. Further, the integration of e.g. educational content (Kiefer et al. 2006b) at these fixed locations makes the gaming progress more attractive to even non-gamers. This helps such a location-based game to address a wider audience.

### 3.2 Acquiring Non-Geographic Data

The classification of Kiefer et.al (2006a) can also be helpful to design games for acquiring no-geographic or geospatial data. Truly spatially continuous games as *Can You See Me Now?* (Benford et al. 2006), feature an unstructured game area without predefined game-relevant locations. In spatially discrete games like GeoTicTacToe (Schlieder et al. 2006, players play in a structured game area with predefined locations for game-relevant actions. Location-based games in a mixed form feature a semi-structured game area. In these cases, game actions are associated with a few real world locations in the game area but can also occur anywhere else.

From the game designer's point of view, a game area is most promising if the geographic data about a game area can all be gathered by the players alone. Therefore, whenever it is possible, location-based games, designed to gather geospatial data in an unstructured game area generate the best results, because it reduces significantly the configuration and orchestration effort (Benford et al. 2005) aligned to every location-based game.

Location-based games, designed to acquire no-geographic or geospatial data, need explicit player interaction to gain the non-geographic part, for example a classification of a (game-relevant) POI. Or the players have to answer a quiz and so generating information about a historical building in the game area. The *goal or sub-goals* of a game (Konzacks, 2002) therefore have to be designed appropriate to realize this kind of user interaction in a meaningful and entertaining way. As a first approach on this topic we present three game design patterns that can be integrated in varied types of location-based games regardless how the game area is structured (see also Figure 3):

The *Transportation pattern,* inspired by the *Hitchers* game from Drozd et al. (2006), lets players move from one game-relevant real world location in the game area to another. In the context of data gathering, these locations should be not only relevant for the game itself but also of interest for non-gaming services like tourist guides. An example would be to bring virtual beer barrels from a historical brewery to any pub found in the game area (Fig. 3, right picture).

By using the *exploration pattern,* players are assigned to search for game-relevant locations by themselves in the game area in order to trigger special game actions there. Finding open or closed WiFi hotspots in *Feeding Yoshi!* Bell et al. (2006) is an example of using this pattern to gather localization/communication network data. Lately, CityExplorer will illustrate the use of this pattern for gathering geospatial data. (Fig. 3, middle picture).

The *Quest pattern* is especially applicable in structured game areas to collect purely non-geographic information. Players are challenged to fulfill information seeking quests at predefined locations. An example would be to collect the prices of hotels in a game area. The player who has found the cheapest hotel at the end of the game wins (Fig. 3, left picture).

It is important that the presented location-based game elements have an appropriately *meaning* (Konzacks 2002) to the player, so that they enjoy themselves in the game and do not consider themselves being a cheap laborer. But as the meaning of a game element changes for every game, we are not able to discuss this subject in general here.

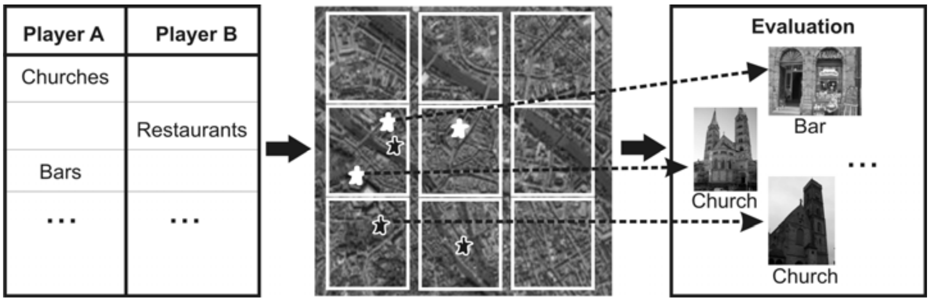


**Fig. 4.** Three phases of CityExplorer: Choosing valid drop location before the game, playing the game and the photo validation after the game

### 3.3 Game Design Example: CityExplorer

In the following, we present a first sketch of a location-based game CityExplorer, with the intension to collecting geospatial data. With this design example, we illustrate particularly the use of the second design pattern, described in 3.2.

The Geogame CityExplorer is a location-based variant of the popular board game Carcassonne, originally designed by Klaus-Jürgen Wrede[2]. 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 city of Carcassonne. Then, they have the choice to place one of their game tokens (followers) on the tile just dropped. Followers can be placed for example on streets, cities or on the markets to control them. A player gets points for the areas their followers hold in control. Once all tiles are laid down, the final scoring takes place. The player with the highest score wins.

CityExplorer adopts the idea that the game area is unknown at the beginning of the game and takes place in an unstructured game area. It can be played by two to n players. But if more than four players are involved, the players should form teams. The exploration pattern is used to place game tokens in this unstructured game area. Since placing tokens is only valid on predefined types of real world locations, as in the original. As a consequence, players are “forced” to collect specific geospatial data. For example players could be allowed to place their followers only near churches or beer gardens found in the game area. In this way, not only geographic coordinates of the corresponding real world objects are collected for free, but also the classification of them. In addition, data about the geographic environment around these game-relevant locations are acquired as well, e.g. the shortest path from one church to the nearest beer garden.

To add a little strategic depth to the game play, the game board is further divided in different regions and players are trying to conquer these regions by placing followers in them. Only the player who holds the majority of game tokens in such a region gets points at the end of the game (see Figure 4, middle).

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[2] http://www.carcassonne.de/ (German only)

Before a round of CityExplorer begins, the players choose the set of real world locations game tokens can be placed to (see Figure 4, left). This pre-game phase is necessary to guarantee fairness. Some players may know the position of beer gardens better than others, who in return may have visited a few more churches recently. To balance such different knowledge levels, players are asked to choose an equal amount of preferred real world locations. All these locations make of the final location set.

Since the game-relevant locations are not known before the game, the verification of set locations can not be automated by the game software. In a post-game phase, the players judge the correctness of the token placement of each other manually. This review process can be simplified if players are asked to take photos of the locations they place their tokens to (see Figure 4, right).

## 4 Use Case Studies: Geogames on the Road

In order to proof the feasibility of our approach to gather geographic data with location-based games, we took our current Geogame variants, GeoTicTacToe (Schlieder et al. 2006) and CityPoker (Kiefer et al. 2007) on tour for about one year. The first game was conducted in March 2006 and the "last" one took place in February 2007.

With these first use case studies, we intent to discover the quantity of data about the geographical environment that can be expected reasonably. Further, we are interested in the quality of the collected data. Although our use case studies concentrate on the examination of GPS trace collections, we claim that our findings hold true for all possible kinds of data about the geographic environment.

We performed gaming events in three cities, Bamberg, Bremen and Coburg (all Germany). 24 rounds of both games were played, exclusive various test runs. The average durance of one game round counts two (GeoTicTacToe) to three hours (CityPoker). The age of participants in these games varied from 10 to 55 years, with an almost equal splitting in gender. Except one or two, all of our players were non-experts in field of geosciences and had never used a mobile device with localization possibility before.

Figure 1 shows a small amount of our data about the geographic environment collected during our game tests and gives a first impression of their quality level. GPS traces of three game rounds of CityPoker are illustrated. See Schlieder (2005) for a detailed description of the game rules.

Our current implementation of the game software records circa every two seconds the current GPS coordinate and saves it in a separate log file. In order to reduce computation time on the mobile device, no further quality checks of the recorded coordinates are implemented. In this way, about 93000 GPS points were collected during all the game tests.

Although only three satellites are necessary to compute a GPS position, the more satellites you get, the more accurate the localization is. In this concern, we filtered all GPS points out of the core data set recorded with a fix from less than four satellites. Depending on the communication protocol of the performing GPS receiver, further accuracy values can also be used to reduce localization errors caused in certain environment, like narrow street canyons which block GPS signals. (Hofmann-Wellenhof et al. 2001). For this evaluation, we restricted ourselves to use only the satellite count, because it is by default available, regardless of the GPS hardware used. With this simple quality constrain, our core data got down to 45600 GPS points. Although around 50% of the acquired geographic data are therefore of relative bad quality, the remaining data still equal a network of approximately 157 kilometer long pathways that can be used by non-gaming location-based services. The means of transport used in our Geogames are bikes and the human feet. For example, the collected GPS traces could be used to enhance routing services of pedestrians or bikers that take most of their data from car navigation services for this purpose today.

According to the official website of Bamberg (Bavaria, Germany), the whole street network of the city is circa 262 km long. We consider that a game round of e.g. CityPoker acquires GPS traces of seven kilometer length in average. We would need, in the best case, only about 37 rounds to gather data about the complete geographic environment of Bamberg. Given a widespread popularity of location-based games, this could be accomplished by a gamer community in just 18.5 days by playing two game rounds daily. Compared with the amount of game rounds played online in e.g. an arbitrary real-time strategy game like Warcraft 3 (http://www.blizzard.com/war3/) that is played by thousand of players a day, this is a very moderate estimation.

## 5 Discussion and Outlook

In this paper, we discussed the idea of encouraging non-expert gaming communities of location-based games to collect geographic data about the real world environment they play in. We proposed a four step approach to design location-based games to acquire geographic data with them. 1.) The kind of geographic data to be collected has to be chosen. 2.) An appropriate structure of the game area has to be defined. 3.) If necessary adequate game elements have to be implemented in the game play to make particularly geospatial data gathering possible. 4.) As a last step, an overall thematic embedding must be found for the game. The design process of CityExplorer was demonstrated to illustrate each of the four steps. A proof of this concept was further given with the presentation of data collections from a one-year tour of two location-based games, GeoTicTacToe and CityPoker, accomplished in three German cities.

Any localization technology used today is not free of errors and even if geographic data are of sufficient quality, qualitative improvements are always appropriate. Geometric aggregation methods described by Morris et al. (2004) can be helpful. For example, redundant collected data, such as the GPS traces in Figure 1, can be aggregated to produce one single data set of better quality. But as Matyas (2007) argues, they are not sufficient enough to handle special cases of redundant geographic data. He proposes an approach that uses geometric measurements in combination with semantic similarity measurements.

An entertaining geographic data acquisition process is surely not enough to build a location-based gaming community that updates built-up data collections on a regular basis. Players need to be committed to the game to keep them playing and building a community. Although they can reuse their collected data outside of the game experience in an associated location-based service, players want to be their data of importance for the actual game experience.

One idea that is already successfully applied to real-time strategy games on the PC is to provide the players a functionality to relive their played games. For example for the strategy game Warcraft 3 players can download replays of played games on various Websites (e.g. www.wcreplays.com). These can viewd inside the game in real-time. Even live audio comments are later added to the replays by other players to analyze and discuss strategic mistakes. Beginners can use this collected wisdom to learn the subtleties of the gameplay quickly – making it easy to enter the community of the game. A first initial evaluation of a prototype for a Geogames replay tool confirms a similar potential for location-based games. Consequently, we are planning to conduct further analysis with a second prototype.

Our future work includes the implementation and evaluation of the presented CityExplorer game. This will enable us to build a geospatial data collection similar to our already existing GPS trace library.

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