Changing the Rules: Acquiring Quality Assured Geospatial Data With Location-based Games

Sebastian Matyas,*
JSPS Fellow,
Higashiikoma, Nara, Japan
email: smatyas7@googlemail.com

Peter Kiefer,
Institute of Cartography and Geoinformation,
ETH Zürich,
email: pekiefer@ethz.ch

Christoph Schlieder,
Otto-Friedrich-Universität Bamberg,
Chair of Computing in the Cultural Sciences,
email: christoph.schlieder@uni-bamberg.de

KEYWORDS
location-based games, crowdsourcing, volunteered geographic information, geospatial data, data quality

ABSTRACT

Location-based games (LBGs) can be used to motivate players to create geospatial data as a by-product of game play (Matyas et al. (2009); Bell et al. (2009)). However, no general design framework for such games identifying all relevant design decisions has been proposed yet. Especially the problem of quality assurance has not been addressed properly in current game design. This paper introduces a new design framework for LBGs specifically targeting at the collection of quality assured geospatial data. The framework uses a game design pattern that aims for quality assurance by using positional accuracy as a quality indicator. We empirically evaluate our approach by comparing the positional accuracy of data collected with and without the game design pattern. Results from the LBGs *GeoSnake* suggest that our pattern results in a significant quality improvement.

Introduction

Previous research by von Ahn and Dabbish (2008) has shown that regular Internet users can be motivated to solve simple tasks, such as HITs (Human Intelligence Tasks) on the Mechanical Turk (`www.mturk.com`) platform without monetary incentives. Using simple web games (`www.espgame.org/gwap/`) they were able to gather large amounts of a data, such as semantic tags for images.

Matyas et al. (2009) have demonstrated that von Ahns basic idea can be adopted for the creation of geospatial data by volunteers with the help of LBGs. However, they reported that, unlike in a pure web-based context, volunteers of LBGs are reluctant to review data created by other players. In contrast to approaches, such as in *Wikipedia* (`www.wikipedia.com`), the evaluation of geospatial data, such as GPS coordinates, can only be done reliably on the ground and not from the computer in your living room. In contrast to previous approaches, such as an external cash-based reward system (refer to Mechanical Turk) or a special review board (refer to Casey et al. (2007)), the approach presented in this paper is inspired by the wisdom of the crowd idea (Surowiecki (2004)). It is realized as a game design pattern that can be integrated in any kind of LBG and succeeds in "persuading" the players to create accurate data right from the start. This pattern, first introduced in Matyas et al. (2011) is now integrated in a design framework and analyzed and discussed in detail.

The main contributions of this paper therefore are: (1) We introduce a new framework for the design of LBGs that motivate to create quality assured geospatial data. (2) We revisit the *wisdom about the crowd* game design pattern (Matyas et al. (2011)). (3) We show that the appraoch results in an improvement of the positional accuracy of the geospatial data collected by the players. We will use the location-based game *GeoSnake* in an experimental setting to evaluate our claim in one case study carried out in the city centre of Bamberg (Germany).

The rest of the paper is structured as follows: in the following section we introduce our design framework that elaborates on three issues important when designing a LBG for the collection of geospatial data: 1. the structuring of a real-world game field 2. motivational game patterns for data collection and 3. strategies for quality assurance. We discuss related work using the concepts of the framework. Then two sections describe the LBG *GeoSnake* and an experiment with this game in which we evaluate the *wisdom about the crowd* pattern. We finally summarize the outcomes of the study and give an outlook on upcoming work.

*special thanks to Kunieda-san and Yamada-san from NEC CCIL

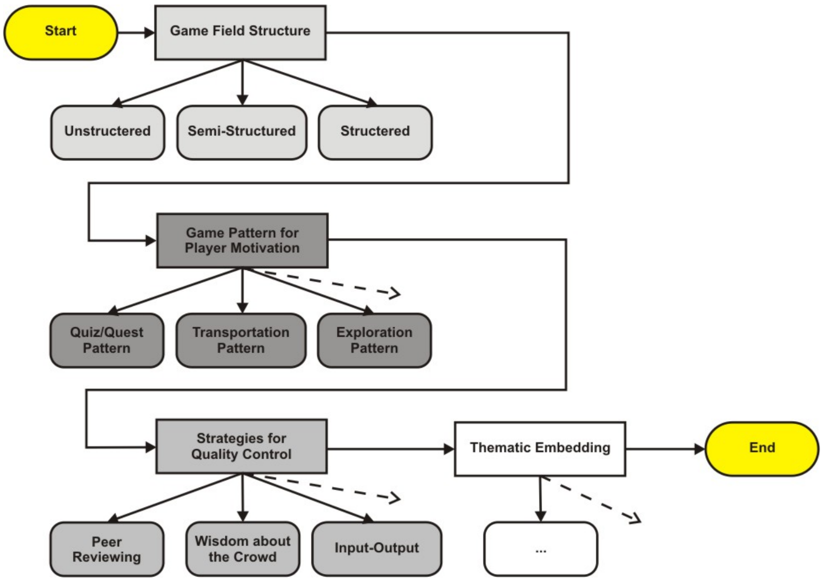

Figure 1: One workflow through the design framework

Design Framework and Related Work

The framework that we introduce is based on the analysis of more than 130 LBGs. This sets our approach apart from previous analyses in the literature of pervasive games - like Montola (2005) - and human computation games - like Yuen et al. (2009) - as they are only used to categorize research fields. A full overview of the analyzed games can be found in the location-based games database (LBGDB) [1] which includes research prototypes and commercial games. Every game was manually encoded with 15 independent attributes ranging from the number of players the game can be played with over the structuring of the game field to the spatial and temporal classification of the game play - see Matyas et al. (2009). Additionally, we looked at existing LBGs that are already used for the creation of geospatial data and analyzed their game elements separately. We could derive three unique attributes for this type of games that also form the basis of the design dimensions of the proposed framework.

As figure 1 illustrates the framework consists of three important design questions:

- *Game field structure:* How should the real-world game field be structured with regard to which type of geospatial data is going to be created with it?

- *Player motivation:* What kind of game elements motivate the players to create geospatial data?

- *Quality control:* How is the quality of the created data assured and evaluated?

[1] http://www.kinf.wiai.uni-bamberg.de/lbgdb/about.php

Note that Fig. 1 only describes one possible way to use the framework. In fact, the design dimensions - game field structure, player motivation and quality assurance - can be seen as independent from each other. As will become apparent in the following discussions, there are patterns for player motivation and game field structures for example that naturally go better together than others (e.g., an unstructured game field fits well with the exploration pattern). But in terms of game play, any combination is possible.

In most cases, the three fundamental design issues can be addressed in the following order (see Fig. 1): the first question is how the real-world game field should be structured as it influences also which kind of geospatial data types can be created - see also Matyas et al. (2009) on this topic. So far, LGBs feature either an unstructured (no game-relevant locations are predefined), semi-structured (some game-relevant locations are predefined) or an structured game field (all game-relevant locations are predefined). The game found in Tuite et al. (2011) is a recent example for the usage of an unstructured game field. In this game the players themselves have to figure out/freely choose where they can/want to perform an game action. They can take photos of any building they want in the game. *CityExplorer* - in Matyas et al. (2009) - was the first LGB designed with the primary goal to create geospatial information. It is designed in a way that players create complex geospatial data sets, composed of two GPS coordinate pairs, image data, and a semantic tag, while playing. It features a semi-structured game field by restricting game actions to take place inside a

predefined tile-based game field. But inside each tile players can choose freely where to take a game action (where game actions in this game mean taking a photo and geo-referencing a building).
LBGs that only log the motion track of each player but allow game actions only on predefined locations on the real-world game field, feature a structured game field.

The next step in the framework is choosing the optimal motivational strategy for the actual data creation part. From the patterns shown in Fig. 1, only the *Exploration* pattern has been used so far - e.g. Matyas et al. (2009) or Tuite et al. (2011). This pattern basically states that players are free to perform game actions anywhere on the real world game field. The two other patterns, the *Quiz/Quest* pattern and the *Transportation* pattern, require the game designer to create some geospatial data before the game, and are therefore not so popular for geospatial data creation LBGs. In the first, players try to solve some sort of quiz or perform some action at a specic location in the real world. In the latter, players bring a game related object from one location to another.

The open problem for all of the previously mentioned approaches is how we can guarantee quality assurance for the collected geospatial data. So far either none - Drozd et al. (2006) - or a point-based review system (*Peer Reviewing* pattern) - Casey et al. (2007), Matyas et al. (2009), Bell et al. (2009)[2] - was used to validate the correctness of the player-created data. Regardless of how one classifies the quality assurance game element of each game, Bell et al. (2009), Casey et al. (2007) and Matyas et al. (2009) reported nearly the same results of how much data was actually reviewed by the players of their games. The review rate was always between 30% to around 40%. Though one could doubt whether these studies constitute a represenative sample they are a strong hint that the upper bound for the quota of data that gets checked with a review-based system is indeed around 40%. But that also means that with such a system half of the collected data has to be seen as of unknown quality as it is only provided by a single non-expert player. Though the quality indicators of the players hardware (e.g. a GPS device) could be known and used as quality indicators, one cannot guarantee that the players have provided false data on purpose. So the review system also serves the role of an anti-cheating tool - Matyas et al. (2009) - and cannot be replaced with some automatic process.

The low evaluation quota motivates our search for other game elements that can be used to assure quality and fairness, while at the same time reaching a higher evaluation quota than 40%.

[2]One could argue that they used the *Input-Output* pattern instead which is based on the idea of a creation and evaluation cycle. Data that is created in one game round is being taken as base data for the next round.

Wisdom about the Crowd Gaming: GeoSnake Study

To overcome the above-mentioned limitations of a game-based review system we propose a new kind of quality assurance strategy for LBGs. The strategy is based on the wisdom of the crowd idea discussed in Surowiecki (2004). With this motivation, and in the spirit of Björk and Holopainen (2004) comprehensive survey of game patterns, we propose the following general game design pattern (shortened version, originally proposed in Matyas et al. (2011). Note the difference in emphasis between "wisdom of the crowd" and "wisdom about the crowd". The former refers to the aggregation of the observations of many individuals while the latter refers to the ability of an individual to make an educated guess about the decisions of others.:

Wisdom about the crowd
Players are retained to take into account the anonymous majority decision of the other players when generating game-based geospatial data.

Although this might not seem very obvious at first sight we will demonstrate the usage of the pattern with the introduction of a simple location-based game, *GeoSnake* - a variant of the popular video game *Snake*. Like the video game, *GeoSnake* is a single-player game. In contrast to the genuine, players have to visit a known number of places and choose appropriate GPS coordinates for them. Players get points for every correctly placed GPS coordinate. Points are deducted if a player crosses his previous path (one point) or takes a path twice (two points) - so every street can be seen as a one-way street and the tail of the snake is growing continuously alongside the path the player takes. Now this might appear easily done, in a real world city wide game field it is quite a challenge. To make the game even more challenging players do not see their already covered path on their mobile device. If a tie in points should occur between two or more players, the one with the shortest path is declared the winner.

For *GeoSnake*, we formulated the following two game rules for how the players should pick a GPS coordinate of a place in the game. The first one is the normal rule that one would expect as a result from the game description we gave above. The second one represents the implementation of the *wisdom about the crowd* pattern:

1. Choose a GPS coordinate that identifies the place without a doubt, so located inside or as near as possible to the place. (rule V1)

2. Choose a GPS coordinate, that you think the other players also chose. (rule V2)

For V1 points were awarded as long the chosen GPS coordinate was reasonable near the place in question. For V2 only those players received points whose coordinate pair belonged to the biggest cluster of coordinates chosen by all players for a place.

The hypothesis is that the players will produce more accurate geospatial data under rule V2 than under rule V1. To judge the accuracy and therefore the quality of the provided geospatial data we proceed as follows with the GPS coordinate of V1 and V2: (1) We compute the cluster centers for all places and then (2) measure all distances between them and the associated GPS coordinates. We then end up with a table that holds all distances for a GPS coordinate to its associated cluster center for both rule variants. Note that although we are looking solely on the positional accuracy of geospatial data here the design pattern can be used with other data types like semantic data (tags) too. To evaluate the effect of the employed rules a generalized linear model (GLM) is estimated Fahrmeir and Tutz (1994).

Case Study: Set-up and Results

In the study 12 students and employees of the university of Bamberg with a background in either computer science (8) or humanities (4) took part. Gender was equally split with 6 male and 6 female participants. The age mean was 26,6 years. All players received an introduction into the game rules and hardware usage shortly before they played the game. All hardware was handed out to the players, a Nokia 6630 smart phone and a XAIOX Wonde-XL that features a Nemerix GPS chip. The game field consisted of twelve places in the city center of Bamberg (Germany) that the players had to choose GPS coordinates for - ranging from places over streets to wide squares. For the evaluation we could get in the best case six GPS coordinates for every place under both rules (V1 and V2) without risking some kind of dependency in the data. To accomplish this, we let the player start with one rule variant and gave them the other inserted in an closed envelope. After six of the twelve places the players had to open the envelope and finish the game using the other rule variant. By changing the starting rule variant with every participant we expected to get an somewhat equal share of GPS coordinates for every place under both rules. The players were free to choose in which order they wanted to visit the 12 places.

Applying the data to the estimated model, which is performed with the R software package[3], produces the following results:

[3] http://www.r-project.org/

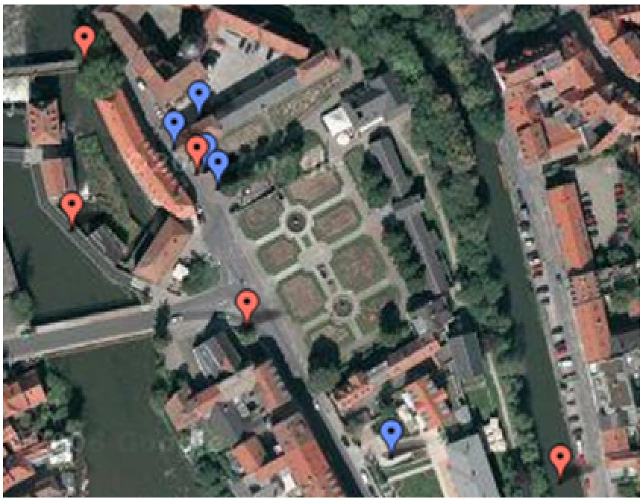

Figure 2: Created GPS coordinates under V1 (red markers) and V2 (blue markers)

For the reason of estimating a GLM with canonical link of a Gamma distributed response with R, the directions of the effects have to be interpreted oppositely in table 1 as R reports the inverse as response. Therefore, *rule 2* is significantly better than *rule 1* though the significance level is only at 0.1.

This result confirms our hypothesis given in section . Furthermore, two interesting results emerged from the informal interviews conducted with each player after they played the game and from a detailed look at the places with a strong data basis. We focused the question if the change in game rules resulted also in an intentional change in user behavior. All of the players reported that they didnt change their "choosing" behavior despite the rule change. This is therefore of great relevance as from a point-wise perspective one would anticipate that the players are more concerned about choosing the "right" GPS coordinate under each game rule. But apparently that is not the main motivator for the behavior change that the data indicates, regardless of the given answers in the interview rounds. As can bee seen in figure 2 - for the area-based place "Geyerswörth" - players choose under V1 GPS coordinates that satisfied their game strategy in contrast to players under rule V2. They choose to set their GPS coordinates near a building that is commonly identified with the place name "Geyerswörth" in Bamberg. The data furthermore shows that for point-

	Coefficient	Std. Error
rule 1 (Intercept)	2.964e-02	5.468e-03
rule 2	1.131e-02*	6.271e-03
time	2.736e-05	6.376e-04

Table 1: Source: *GeoSnake* Game. Remarks: *** < 0; ** < 0.05; * < 0.1

like places like small buildings, places or monuments the difference in accuracy between rule V1 and V2 is negligible. Here the differences only result from the different GPS signal conditions, but not from different player behavior. With these results in mind we prepared a second study which is described in Matyas et al. (2011) and results in a support of our hypothesis with a high significance level of 0.05. It also solved hardware problems that let players record an equal share of GPS coordinates for every place that was not achieved in the above described study. For some only small numbers of coordinate pairs were available.

Conclusions and Outlook

In this paper we have shown that the problem of low participation rate which is common for review systems of location-based games can be overcome by implementing the *wisdom about the crowd* design pattern. We presented the general design pattern and the location-based game *GeoSnake* to illustrate its use. Additionally we used the *Geosnake* game in the course of two case studies to validate the hypothesis that with my proposed game pattern the spatial accuracy of the collected data can be increased. Informal interviews and detailed data analysis point out that these results are independent of the point-based game rewards used in *GeoSnake*. Related work suggests, e.g. Casey et al. (2007), that when geospatial data creation is paired with a location-based game players are more concerned about the game and not so much about the data creation task at hand. Our research indicates that this behavior changes when the *wisdom about the crowd* pattern is applied to the game. In our future work we will investigate more design patterns to tackle the information quality problem that comes with the usage of location-based games as crowdsourcing tools for geospatial data. Bishr et al. (2008) Bishr and Mantelas (2008) have already argued that quality is one of the most pressing matters when it comes to "Collaboratively Contributed Geographic Information (CCGI)" - their name for VGI data. They presented a model to compute the quality of a CCGI by using trust as a proxy. We would like to combine trust and quality values in a unique quality assurance method in the future.

REFERENCES

Bell M.; Reeves S.; Brown B.; Sherwood S.; MacMillan D.; Ferguson J.; and Chalmers M., 2009. *Eye-Spy: supporting navigation through play.* In *CHI 2009.* ACM. ISBN 978-1-60558-246-7, 123–132.

Bishr M. and Mantelas L., 2008. *A trust and reputation model for filtering and classifying knowledge about urban growth. GeoJournal*, 72, no. 3, 229–237. ISSN 0343-2521.

Björk S. and Holopainen J., 2004. *Patterns in Game Design (Game Development Series).* Charles River Media, Inc., Rockland, MA, USA. ISBN 1584503548.

Casey S.; Kirman B.; and Rowland D., 2007. *The gopher game: a social, mobile, locative game with user generated content and peer review.* In *ACE 2007.* ACM. ISBN 978-1-59593-640-0, 9–16.

Drozd A.; Benford S.; Tandavanitj N.; Wright M.; and Chamberlain A., 2006. *Hitchers: Designing for Cellular Positioning.* In *Ubicomp 2006.* Springer, LNCS 4206, 279–296.

Fahrmeir L. and Tutz G., 1994. *Multivariate Statistical Modelling Based on Generalized Linear Models.* Springer, New York.

Matyas S.; Kiefer P.; Schlieder C.; and Kleyer S., 2011. *Wisdom about the Crowd: Assuring Geospatial Data Quality Collected in Location-Based Games.* In *ICEC 2011.* Springer, LNCS 6972. ISBN 978-3-642-24499-5, 331–334.

Matyas S.; Matyas C.; Mitarai H.; Kamata M.; Kiefer P.; and Schlieder C., 2009. *Designing Location-based Mobile Games - The CityExplorer Use Case*, Peter Lang Publishers. ISBN 978-1-4331-0532-6, 187–203.

Montola M., 2005. *Exploring the Edge of the Magic Circle: Defining Pervasive Games.* In *Proc. Of Digital Experience: Design, Aestethics, Practice.*

Surowiecki J., 2004. *The wisdom of crowds: Why the many are smarter than the few and how collective wisdom shapes business, economies, societies, and nations.* Doubleday, New York. ISBN 9780385503860.

Tuite K.; Snavely N.; Hsiao D.y.; Tabing N.; and Popovic Z., 2011. *PhotoCity: training experts at large-scale image acquisition through a competitive game.* In *CHI 2011.* ACM. ISBN 978-1-4503-0228-9, 1383–1392.

von Ahn L. and Dabbish L., 2008. *Designing games with a purpose. Commun ACM*, 51, no. 8, 58–67.

Yuen M.; Chen L.; and King I., 2009. *A Survey of Human Computation Systems. Computational Science and Engineering, IEEE International Conference on*, 4, 723–728.