Participation Patterns, VGI and Gamification

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Abstract

This article studies the spatial behavior of contributors to OpenStreetMap and links it to gamification mechanisms which provide a solution to issues that arise with patterns of participation. More specifically, three issues are identified: (1) high productive contributors show little commitment to return and update geographic features they created, (2) the gap between the accumulated percentage of created features and the accumulated percentage of updated features is widening, (3) there is a significant contrast between areas of high and low mapping activity. Spatial allocation games are described as a subclass of location-based games suitable for addressing the participation issues. Based on an analysis of the geogames Geographing, Foursquare, Ingress, and Neocartographer six common design patterns for the allocation and deallocation of places are identified. It is shown how the participation issues map onto the game design patterns. Results from an agent-based spatial simulation provide insights into the interaction of the spatial design pattern.

Keywords: location-based games, geogames, volunteered geographic information, OpenStreetMap

1 Introduction

Following the successful paradigms of Web 2.0 (O' Reilly 2005) such as Wikipedia, the Geospatial domain entered the Web 2.0 era leveraging the user generated spatial content, more publicly known as Volunteered Geographic Information (VGI, Goodchild 2007). The most successful example so far has been OpenStreetMap (OSM). OSM has motivated thousands of users to create a free map of the world providing a strategy to overcome limitation that prohibited National Mapping Agencies (NMAs) around the world to fulfil their main aim: to provide up-to-date geographic information (GI).

While OSM is quickly building a world map of free data, challenging points in the whole process appear. One of the most discussed issues in the literature is the VGI data quality and fitness-for-purpose, usually using OSM data as a paradigm (see for example Haklay 2010, Haklay et al 2010, Antoniou 2011, Koukoletsos and Haklay 2012). Another closely related issue is the observation that new sources of uncertainty, which are related with social phenomena, have started to emerge for VGI and are fundamentally different from those known for the authoritative datasets (Antoniou 2011). This is mainly due to the social aspect of the VGI phenomenon and the crowd-based mechanism for data collection. As all these boil down to the question about how the crowd behaves, academic research has focused on the theoretic analysis of the contributors, their nature and their motivation (Goodchild 2007, Coleman et al 2009) or their new role in the GI production (Budhathoki et al. 2008).

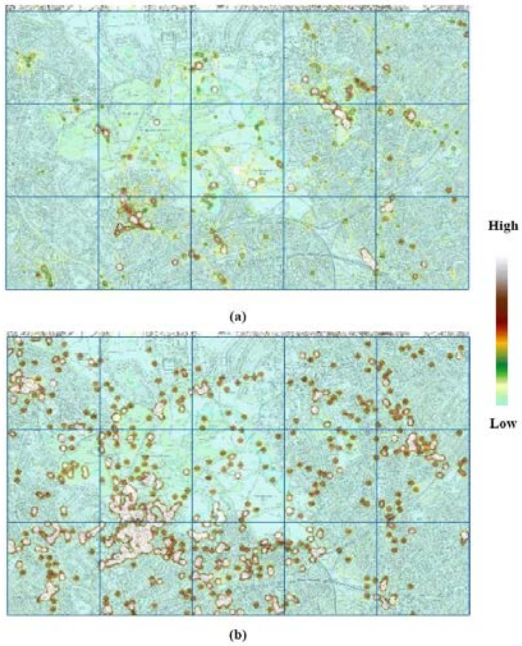
On the other hand, empirical research has shown that contributors are affected by the underlying socio-economic context of their activity area. For example it has been shown that there is correlation between the Index of Multiple Deprivation for the UK and the OSM completeness (Haklay 2010) or OSM positional accuracy (Antoniou 2011). Interestingly enough, when examining other sources of VGI such as the popular photo-sharing web applications of Flickr or Picasa Web that provide geo-tagged images, similar patterns emerge. Particularly for Flickr (www.flickr.com) research (Antoniou et al. 2010) has shown that by conducting a density analysis of geo-tagged images there are certain areas that attract users more than others. However, the same spatial analysis on the geo-tagged images of Geograph (www.geograph.co.uk), which is a spatially explicit application that implements a gamification approach, has shown that it provides a better area coverage even with fewer photos compared with Flickr (7993 Flickr photos vs 1109 Geograph photos) (see Fig. 1).

Following this line of research, this paper investigates the participation patterns of OSM contributors, the results produced, the impact that these patterns can have on spatial data quality and provides remedies for counter-balancing unwanted effects

2 The OpenStreetMap Case Study

The focus area is the Greater London Area in the UK, as the birthplace of OSM is University College London. Moreover, urban areas attract more OSM contributors and thus such areas facilitate the monitoring and the analysis of their digital behavior. Instead of a direct bulk download from the OSM database, the dataset of the area was downloaded in a shapefile format (by www.geofabrik.de) and then the OSM API was used to collect only the necessary data for the analysis (changesets, timestamps etc.) using the unique osmid of each feature. The dataset contains 438,980 features that have in total 917,000 versions, contributed by 3,230 OSM contributors.

Figure 1: Density surfaces for (a) Flickr and (b) Geograph in a test area of 3x5km in North London.



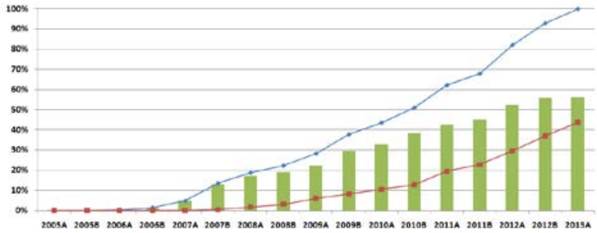
Source: Antoniou et al. 2010

The analysis of the OSM datasets aimed to provide answers to the following questions:

1. Is there a commitment between OSM contributors and their spatial edits?
By analyzing the behavior of the most productive contributors (i.e. those that have contributed more than 100 times) it has been revealed that there is no such thing as relationship between creators and spatial features. In fact, just a mere 10% of these high productive contributors are returning to more than 20% of the features that have created in the past. This observation is creating a fresh line of questions regarding the notion that contributors are bringing along their local knowledge and the importance of this knowledge in the quality of the OSM dataset.

2. Is the OSM dataset kept up-to-date by the OSM contributors?
By comparing the accumulated percentage of created features with the accumulated percentage of updated features during time, it is revealed that there is a steadily growing difference between those two categories (Fig. 2). For the first semester of 2013 the difference climbed to 56% of the geographic entities. This observation leads to the disturbing conclusion that a growing number of OSM features are falling behind when the up-to-date factor is considered. This is even more interesting as the analysis shows that more contribution effort is focused on data updating than data creation.

Figure 2: The accumulated % of created features (blue line) vs the accumulated % of updated features (red line) by semester. The green bars show the % of difference in the number of features.



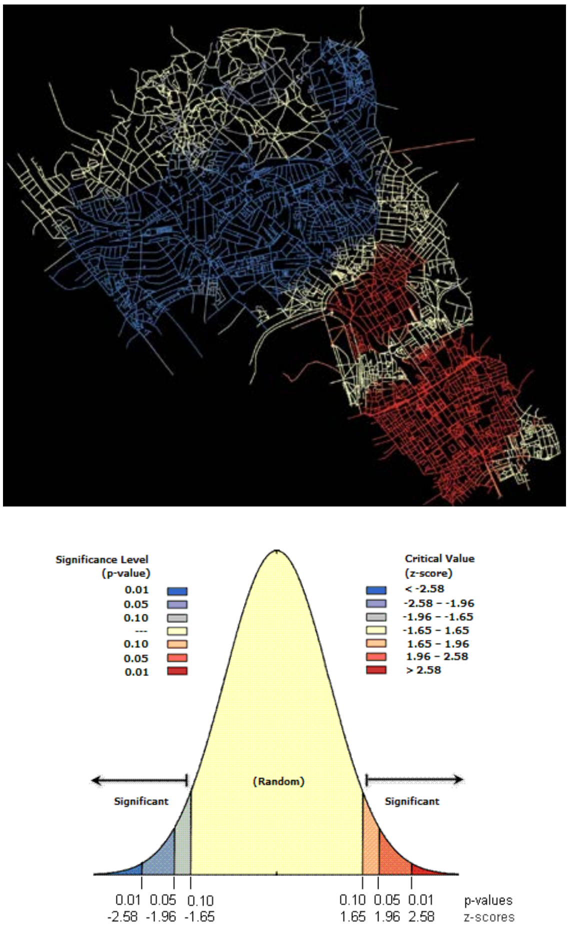
3. Is there any spatial pattern in the OSM contributors' behavior?
By applying spatial statistics analysis (Hot Spot Analysis) on the dataset using the number of versions of each OSM feature it was possible to identify statistically significant spatial clusters of both high values (hot spots) and low values (cold spots). Figure 3 shows the streets of the London Borough of Camden. The Hot Spot Analysis based on the versions of each road segment reveals which areas are attracting the interest of OSM contributors and which are not. It should be noted that the hot areas are the area around UCL (lower red) and the Camden Market (middle red). This observation shows that users are focusing their contribution on specific popular and well-known areas while overlooking others more obscure ones. This is in accordance with previous observations about the correlation of socio-economic factors and contribution mentioned above.

The analysis of the OSM dataset shows that the evolution of VGI brought along new uncertainty sources for the spatial data available on the Web. The evidence is growing that apart from the classic spatial quality elements (ISO 2005) there are social elements that are influential to the quality factor. It is worth noting that these social elements are totally different to the error sources that usually affect classic GI production mechanisms followed by national mapping agencies. Consequently, the VGI opens up new areas for further research in the subject matter of spatial data quality and in the evolution of OSM initiative (or similar ones) in the long run. It is clear that if OSM aspires to become a world-class spatial database, or even to preserve its current status, then measures to counter-balance such phenomena should be taken into consideration.

3 Spatial Gamification

Crowd-based mapping shares some characteristics with the game playing activities in geographic space that have become popular recently, such as Google's global multi-player game Ingress (Hodson 2012) or the gamification mechanisms of the location-based social network Foursquare (Lindqvist et al. 2011). In such location-based geogames, the geographic location of the player constitutes a fundamental game element since different places in the geographic environment are associated with different choices of game actions (Schlieder et al. 2006). This motivates players to visit places which they probably would not visit outside the game. Not surprisingly, researchers have started to study geogames as a means to increase participation in VGI. Examples include the photographing and geo-referencing of buildings (Matyas et al. 2009) or the mapping of noise in an urban environment (Garcia-Martí et al. 2013). However, little is known on how to relate the participation issues of VGI mapping to specific design patterns of geogames.

Figure 3: OSM participation pattern based on the versions of each feature.



The following analysis concentrates on the design of the game mechanics, that is, the set of rules which define the sequence of game actions (Montola et al. 2009, Adams and Dormans 2012). Geogames are played as search games or chase games or they follow some other paradigm, frequently, a paradigm drawn from pre-computer outdoor games (Davidson et al. 2004). The many variants of capture-the-flag games constitute such a time-tested paradigm. Places in the geographic environment act as resources that the mechanics of the geogame allocates to the players according to a variety of rule sets. This analysis refers to such games as *spatial allocation games*.

Geographing, the photographic mapping game discussed in the related work section, is a spatial allocation game in which the player's task consists in submitting the first geographically representative photograph for squares of the Ordnance Survey grid of Great Britain and Ireland (www.geograph.org.uk). The spatial allocation paradigm has been interpreted in many different ways as three other geogames illustrate. *Foursquare* primarily offers the services of a location-based social network, however, its check-in mechanism adds a game playing experience (foursquare.com). Users who check-in at places with a mobile device are rewarded for frequent re-visits by becoming the "major" of the place. *Ingress* is a geogame in which two teams of players compete to capture and re-capture places called "portals" on a global game board (www.ingress.com). The game comes with a complex game mechanics which – to simplify considerably – allocates a portal to the team of the player who visits the place while being in possession of the appropriate game resources and knowing how to best deploy them tactically. *Neocartographer* has been designed by the second author of this article as a game for two competing players or teams. The players try to obtain places which form a particular spatial configuration, instead of just maximizing the number of places in their possession (www.geogames-team.org).

4 Design Patterns for Allocation Games

Some fundamental design choices apply to all types of geogames as pointed out by Montola et al. 2009. Geogames are either played on a bounded game field or without spatial restrictions anywhere in the global geographic space. In the temporal dimension, the game can last for a limited playing time or can go on without end (pervasive play).

The specific design choices for spatial allocation games have not been systematically described in the literature. For the purpose of this analysis, two design parameters are considered: allocation type and place-to-player ratio. In three of the four example games, place allocation is exclusive, that is, a place can only be allocated to one player or team at a time. Foursquare, where several users can check-in at the same place and earn badges for these check-ins, uses multiple allocation in combination with exclusive allocation for awarding the title of major of a place.

A simple metrics reveals further differences, the ratio of places to players. Geographing is played, as of April 2014, by 12,038 players (accounts) on 331,956 places (grid cells). This gives a place-to-player ratio of approximately 30. In contrast, the Foursquare website states for the same period that more than 1,500,000 places (venues) created by businesses are visited by more than 45,000,000 players (patrons) which amounts to a ratio of 1/30. Ingress does not publish global player statistics. However, since only two teams compete, the ratio is of the same order of magnitude as the global number of portals. A typical Neocartographer game where two players compete for half an hour is played with 10 places, that is, with a place-to-player ratio of 5 (Table 1).

Most geogames with a large place-to-player ratio are based on a mechanics with exclusive place allocation. In OSM mapping, the geographic features outnumber the mappers by far with a place-to-player ratio even higher than that of Geographing or Ingress. A global and pervasive game play with exclusive allocation suggests itself as design choice for a gamification approach to OSM mapping. Different game design patterns for allocating and deallocating places are consistent with this choice. An allocation pattern describes the game mechanics which specifies what players need to do in

Table 1: Design parameters of spatial allocation games

	spatial boundary	temporal boundary	allocation type	Place-to-player ratio
Geographing	game field	pervasive play	exclusive	$10 < r < 100$
Foursquare	global	pervasive play	multiple	$10^{-2} < r < 10^{-1}$
Ingress	global	pervasive play	exclusive	$10^{4} < r < 10^{5}$ (?)
Neocartographer	game field	playing time	exclusive	$1 < r < 10$

Table 2: Design patterns for allocating places

	mechanics	design objective	example
First-to-visit	the place goes to the first visitor	spatial coverage	Geograph points (Geographing) claiming a portal (Ingress) claiming a cell (Neocartographer)
Nth-to-visit	the place goes to the n-th visitor	game balancing	second visitor points (Geographing)
Most-revisits	the place goes to the most frequent visitor	revisit frequency	mayor of a place (Foursquare)

Table 3: Design patterns for deallocating places

	mechanics	design objective	example
Never	the place is allocated for the whole game	simplicity	Geograph points (Geographing)
When-claimed	The allocation changes if another player meets the allocation criterion	data recency game balancing	Reclaiming portals (Ingress)
When-decayed	after a time span, the allocation is cleared	game balancing	energy loss of resonators (Ingress) moving time window (Foursquare) time-gap points (Geographing)

order to obtain a place. A widely used mechanism consists in allocating the place to the first visiting player (first-to-visit pattern, Table 2). In a later stage of the game, when most of the places have been allocated to their first visitors, some games employ an additional mechanism which awards the place also to the second or even third visitor in a multiple allocation scheme (nth-to-visit pattern, Table 2). Geogames with a small place-to-player ratio tend to reward players who revisit a place (most-revisits pattern, Table 2).

Deallocation mechanisms counteract the consumption of places by allocation mechanisms. Some games, such as the original version of Geographing, do not use deallocation at all (never pattern, Table 3). The most popular mechanism for competitive two player-games permits the player to reclaim a place from the opponent. In the simplest form, a place is reallocated any time one of the two player visits it (when-reclaimed pattern, Table 3). Another solution consists in using a decay time after which places are freed (when-decayed pattern, Table 3).

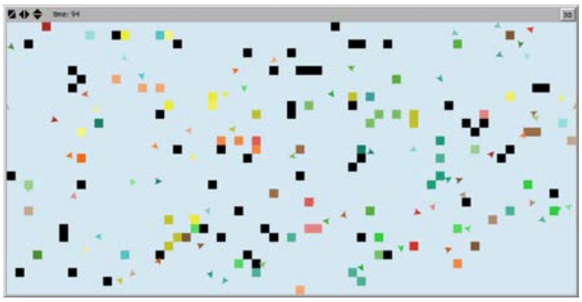
Although the listed design patterns for allocation and deallocation do not provide an exhaustive inventory of design choices, they help to identify possible gamification approaches to the quality issues of OSM mapping. The design objective of maximizing the revisit frequency matches the problem that OSM contributors show little commitment to their edits (most-revisits pattern, Tab. 2). Similarly, the when-reclaimed pattern for deallocation motivates players to visit places which other players have visited before. It permits to address the design objective of data recency in a VGI game context. The issue of spatial regularities in the behavior of OSM contributors seems more complex as it reflects the effects of socio-economic factors. Gamification might still counteract the spatial clustering of mapping activities. The first-to-visit pattern combined with exclusive allocation is a well-tried mechanism for maximizing the spatial coverage of in-game activities.

5 The Problem of Accumulated Advantage

Unfortunately, very little is known about how the design pattern for spatial allocation games interact. As most geogames do not permit to modify their game mechanics, the causal effects of game pattern cannot be studied by field-testing. An alternative approach which has been successfully applied to the design of video games consists in using simulations (Adams and Dormans 2012). To gain a better understanding of the interaction of the first-to-visit allocation pattern with the deallocation patterns, an agent-based simulation was implemented in the NetLogo 5.05 environment (Wilensky

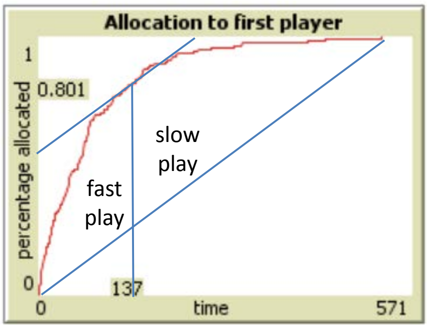
2012). In the simulation, the players (VGI mappers) move through the environment until they happen to encounter a new geographic feature or a feature that needs updating. Every feature is represented by a cell in the simulation environment. The movements of the players are generated by a constant velocity random walk direction mobility model (Roy 2011).

Figure 4: Simulation study: unallocated places (black cells), allocated places (colored cells), and players (colored triangles)



A first set of experiments studied exclusive allocation to the first visitor with no deallocation similar to the game mechanics of the original version of Geographing. Since allocation is exclusive and places constitute a finite resource, place allocation should slow down with time. Interestingly, a single form of slowdown consistently emerged in all simulation runs. Figure 5 shows the percentage of allocated places as a function of the time played for a typical simulation run. In this case, 80% of the places are mapped by some player after 137 simulation cycles. The empirical curve is fitted by a concave function which permits to distinguish two phases: a phase of fast play during which the allocation change is above average followed by a phase of slow play during which allocation change is below average. At the phase transition roughly 80% of places have been mapped in a little more than 20% of total playing time. For obvious reasons, the slow play phase is not very attractive to human players. Players experience most success, in the sense that they are mapping features, during the first part of the fast play phase when there are more places than players.

Figure 5: First-to-visit allocation with no deallocation



The simulation reveals another problem of a game mechanics based on exclusive first-to-visit allocation with no deallocation: the outcome of the game is predictable at an early phase. From the top 10% highest scoring players at the moment when 50% of places are mapped, most will still be among the top 10% at the end of the game. An advantage early in the game accumulates with this game mechanics. This phenomenon is called the problem of accumulated advantage in game design. To avoid the slow-down, first-to-visit allocation without deallocation should not be played beyond the point of 50% mapped places. Note that Geographing which implements this pattern has already allocated 82% of the places to players. Based on the simulation results, one would predict that a spatial allocation game at this stage is mostly of interest to the highest performing players. This prediction is consistent with the high score lists published by the Geograph project which show little change over the course of the years.

Remediating the problem by deallocation is not straightforward. A second set of experiments combined exclusive allocation to the first visitor with the when-reclaimed deallocation pattern, a combination frequently found in competitive two player geogames. The simulation runs show a slowdown of the places being allocated for the first time which is comparable to the simulation runs without deallocation (Figure 5). The slowdown, however, has little effect on the gaming experience since the players may reclaim places that were previously allocated to other players. Furthermore, the simulation runs consistently show that a new type of problem with the game balance emerges: the outcome of the game becomes too unpredictable as it is virtually decided in the last cycles of the simulation. For the playing experience, advantages which do not accumulate at all are as frustrating as advantages which accumulate too fast.

6 Conclusions and Outlook

This paper presented first results relating participation patterns in VGI to gamification mechanisms which can help to address participation issues. A case study from the Greater London Area revealed three spatial pattern in the behavior of OSM contributors. High productive contributors were found to show little commitment to return and update the geographic features they created (commitment problem). Secondly, the gap between the accumulated percentage of created features and the accumulated percentage of updated features is widening (update problem). Thirdly, the spatial analysis of OSM feature version shows a contrast between areas of high and low mapping activity (clustering problem).

The remaining sections of the paper described spatial allocation games as a class of geogames suitable for a gamification approach to VGI mapping. Two design choices specific to allocation games were identified, the allocation type and the place-to-player ratio. The analysis of the geogames Geographing, Foursquare, Ingress, and Neocartographer helped to specify six common design patterns for the allocation and deallocation of places. It was shown how to map the VGI participation issues onto design patterns. The commitment problem is addressed by the most-revisits allocation pattern, the update problem by the when-reclaimed deallocation pattern, and the clustering problem by the first-to-visit allocation pattern.

An agent-based simulation study revealed that even the simplest patterns interact in an intricate way. Geogames based on the first-to-visit allocation pattern without deallocation exhibit problems with game balancing because of accumulated advantages early in the game. Using the when-reclaimed pattern instead, resolves this problem but creates a new one because advantages do not accumulate sufficiently.

To the best of our knowledge, simulations studies have not been systematically used to design geogames. Our first results are encouraging. The simulation correctly reproduced the problem of accumulated advantage which arises in the Geographing game and links it to first-to-visit allocation pattern. As for any type of simulation, realism constitutes a challenge, especially, when it comes to modeling player motivation. However, the costs for play testing geogames are much higher than for classical video games which is why simulations offer an interesting alternative to study their game mechanics.

Future research will explore more complex game mechanics which go beyond the combination of a single positive feed-back loop (allocation) with a single negative feed-back loop (deallocation). The results obtained so far show that agent-based simulation provides a valuable method for avoiding the repeated modifications of the game mechanics by trial and error which geogames currently impose on their players.

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