GEOGRAFSKE INFORMACIJE MNOŽIČNIH VIROV S PRISTOPOM NA TEMELJU IGER

CROWDSOURCING GEOGRAPHIC INFORMATION WITH A GAMIFICATION APPROACH

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IZVLEČEK

V zadnjih dveh desetletjih se pogosto srečujemo z geografskimi informacijami množičnih virov, zaradi katerih sta se izredno spremenila vloga in pomen geografskih podatkov v družbi. Razpoložljivost in uporabnost geografskih informacij sta bistvenega pomena za tako rekoč vse programske sisteme in storitve, kar je močno odvisno tudi od tega, koliko so se posamezniki pripravljeni angažirati za zbiranje oziroma izboljšavo podatkov. Ključno za oblikovanje sistemov, s katerimi bi povečali zadovoljstvo uporabnikov in samo učinkovitost, je razumevanje motivacije ljudi, da sodelujejo v tem procesu. V pričujoči raziskavi o množičnih virih geografskih podatkov smo uporabili metodo iger – tako imenovana igrifikacijo. Pristop se pogosto uporablja za spodbujanje ljudi k vključevanju v dejavnosti, ki se skrivajo za »pročeljem« igre. Ključna dejavnika, ki se spodbujata z igro, sta sodelovanje in tekmovanje. V raziskavi smo oblikovali konceptualni model, v katerem se zbirajo glavne tehnike iger, ki so prilagojene za geografske podatke in so podlaga za vzpostavitev knjižnice iger. Za preverjanje koncepta smo razvili rešitev za Android, namenjeno zbiranju geometričnih podatkov o notranjosti stavbe, kar smo preizkusili v nevtralnem okolju.

ABSTRACT

Crowdsourcing geographic information has been a massive phenomenon that took place over the last two decades and that changed dramatically the diffusion of geographic data in society. The availability and readiness of geographic information is paramount in practically all software systems and services and this is strongly determined by the drive of people putting energy in data collection and improvement. Understanding the motivations of people to participate in this process is fundamental to leverage the design of new systems able to increase satisfaction and productivity. The introduction of game mechanisms in geographic crowdsourcing is the theme that we face in this research. The so-called gamification of applications has been widely used as a stimulant for involving people in serious activities that are hidden behind the gaming façade. Cooperation and competition are key factors that are promoted through the game. We synthesize a conceptual model that collects the main gaming techniques tailored for geographic data and that is the basis for the development of a gamification library. As a proof of concept, we deploy an Android app for geometric data collection inside buildings and test it in a university setting.

KLJUČNE BESEDE

prostovoljne geografske informacije, podatki množičnih virov, metoda iger, igrifikacija, mobilna rešitev

KEY WORDS

Volunteered Geographic Information, data crowdsourcing, game method, gamification, mobile app

1 INTRODUCTION

The phenomenon of crowdsourcing geographic information has been named Volunteered Geographic Information (VGI) in Goodchild (2007). Since its inception, the phenomenon has revolutionized the way geographic data permeates society, up to the point where virtually any software application includes a location component and almost all users contribute to share information of geographic kind (Elwood, Goodchild, and Sui, 2012). Notoriously, legacy systems have obstructed the free diffusion of geographic data in the past and most available data sets are the result of a volunteered sharing process. Motivating people in keeping alive the interest in crowdsourcing is therefore an important issue. An approach based on gamification is by no means a secondary or funny approach, but it represents a key to immediately involve people in a cooperative effort to broaden geographic knowledge and share it with anybody.

Gamification is based on the use of gaming techniques in the design of general software applications (Deterding et al., 2011). Starting by the analysis of gaming techniques already introduced in existing geographic systems, we define a gamification framework specifically tailored for geographic applications. Users of the framework will get several advantages such as: (i) having a guide that helps to delineate a clear path on how to apply gamification, minimizing errors and saving time and money; and (ii) increasing the chances of success by reusing previous knowledge. From the conceptual specifications, we developed a gamification library for mobile applications that can be used as a common software component for many apps in the geographic context. As a case study, we used the gamification library to obtain a gamified version of an existing app, namely CampusMapper that serves to collect spatial data in indoor university facilities. The gamified app called CampusMapperGamified has been tested with a group of users with the general goal of checking the applicability of gaming mechanisms to VGI and of assessing trustworthiness of collected data, that is, the degree of confidence with which we can rely on such data.

A preliminary version of this paper without a description of the gamification library and the user evaluation has appeared in Martella, Kray, and Clementini (2015). The paper is organized as follows. In Section 2, we present the state of the art in geographic crowdsourcing and gamification. In Section 3, we introduce our conceptual framework for gamification of geographic applications. In Section 4, we introduce the gamification library for Android applications. In Section 5, we present a case study related to the gamification of CampusMapper. In Section 6, we discuss an evaluation with end-users. Section 7 concludes the paper.

2 RELATED WORK

As a basis to construct our framework, in this section we discuss open challenges for VGI, motivations driving people in crowdsourcing, the ideas behind games and gamification, and the application of gamification to crowdsourcing, especially in existing geographic systems.

2.1 Open Challenges for VGI

OpenStreetMap (OSM) (http://openstreetmap.org) is one of the largest and most famous VGI projects with a growing number of users. OSM is based on the recording of individuals' positioning (GPS) data to create up-to-date maps of the user location. Individuals take the role of living sensors to measure their own environment (Goodchild, 2007). Flickr is another example (http://flickr.com), which provides large amounts of geographic data through photographs shared by subscribers, which are normally indexed by location as well. Therefore, Flickr is an example of a system that produces geographic data, but in most cases its users are not interested in geography (Flanagin and Metzger, 2008). In Fritz et al. (2009), authors discuss the challenges in VGI domain. As the first and most important challenge, they identify the problem of attracting a consistent number of volunteers. To this regard, in Celino (2013), authors claim that volunteers need to be motivated to be cooperative. Fostering collaboration, however, requires a proper incentive strategy: for instance, OSM represents a wiki-like collaborative platform, where users are driven by the same needs and ethical principles. Often this approach is not enough, because volunteers should be stimulated to remain active to obtain a comprehensive and uniform result and to consider the changes that constantly happen (Goodchild, 2008). In (Fritz et al., 2009; Fritz, See, and Brovelli, 2017), authors point out that this first challenge can be solved by competitive games such as those used for most computer games; they could be implemented to make the challenge of geographic crowdsourcing more attractive.

A second challenge is related to data quality assurance for VGI data (see e.g. Flanagin and Metzger, 2008; Fogliaroni, D'Antonio, and Clementini, 2018; Qian et al., 2009). Volunteered information is by nature unpredictable and discontinuous; therefore, its reliability can be assessed only in statistic terms. In Goodchild and Li (2012), authors describe three approaches to quality assurance without resorting to external data sources, the "crowdsourcing", "social", and "geographic" approaches, respectively, discussing the advantages and limitations of each. The crowdsourcing approach assumes that quality increases with the number of contributors: the underlying principle supporting this claim is known as the many-eyes principle: if something is visible to many people, then, collectively, they are more likely to find errors in it. Publishing open data can therefore be a way to improve its accuracy and data quality (http://opendatahandbook.org/glossary/en/terms/many-eyes-principle). Therefore, in Goodchild and Li (2012), authors conclude that the crowdsourcing approach does not properly apply to less known facts, such as geographic features located in a sparsely populated area. Indeed, in this case, the many eyes needed to assure the quality would be missing. The second approach mentioned in Goodchild and Li (2012) was named "social": it relies on the construction of a hierarchy of moderators, i.e., individuals that are reputed trustworthy in the community because of the quality of their contributions. The third approach is termed "geographic" and it is the one that is best suited for full or semi-automatization: it decides on the quality of a feature by comparing it against geographical laws - e.g., a shoreline should have a fractal shape.

2.2 Motivations of Crowdsourcing Contributors

Understanding motivations can be done by considering the profile of the candidate contributors. In Coleman, Georgiadou, and Labonte (2009), authors classify the types of people who volunteer geospatial information into the following categories: neophyte, interested amateur, expert amateur, expert professional, and expert authority. They also identify a list of motivations for user contributions and analyze how many of them apply to VGI applications. Among the constructive motivations, they identify altruism (e.g., restaurant reviews where the goal is to pass along information regarding good restaurants), professional interest, intellectual stimulation, social reward and enhanced personal reputation. In the case of damaging motivations, they identify mischief (e.g., vandalism) and criminal intent. In psychology, people's motivation can be either intrinsic or extrinsic. Extrinsic motivation comes from an outer stimulus, such as in the case of earning a reward or avoiding a punishment, while intrinsic motivation comes from an inside perception of reward, such as fun, altruism, or ambition. Based on such a distinction, in Kaufmann, Schulze, and Veit (2011), authors developed a framework for paid crowdsourcing environments (e.g., Amazon Mechanical Turk - http://mturk.com), where participants are motivated both on an intrinsic and extrinsic basis. Similarly, in Eickhoff et al. (2012), authors suggest that participants on a crowdsourcing environment can be subdivided in money-driven workers (extrinsic motivation) and entertainment-driven workers (intrinsic motivation).

2.3 Gamification as Intrinsic Motivator

Self-Determination Theory (SDT) by Ryan and Deci (2000) introduced principles to foster intrinsic motivations instead of extrinsic ones. Those principle have been transposed to gamification by Aparicio et al. (2012), Deterding (2011), and Groh (2012): in detail, they point out that relatedness (the universal need to interact and be connected with others), competence (the universal need to be effective and dominate a problem in a given environment), and autonomy (the universal need to control one's own life) are needed to keep alive intrinsic motivations of users. Furthermore, several empirical studies find strong correlations between video game features, need of satisfaction, and other relevant constructs like enjoyment or intrinsic motivations (Mekler et al., 2017; Sailer et al., 2017; Xi and Hamari, 2019). Regarding the use of game mechanisms as a motivator to collect geographic information, in Celino (2013), authors observe that gamification of data collection is an incentive scheme for VGI. In Davidovic, Medvedeva, and Stoimenov (2013), authors present a location-based game called MapSigns that is used for mapping real world objects as side products of the game. In Crowley et al. (2012), authors refer to a social reporting application where they added game mechanisms to engage users. The player is at the root of gamification: in Zichermann and Cunningham (2011), authors answer the question: "Why people play?" by identifying four underlying reasons, which can be viewed together or separately: to master, to relieve stress, to have fun, or to socialize. In Bartle (1996), by studying players of Massively Multiplayer Online Games (MMOGs), authors identified four types of players: explorers, achievers, socializers, and killers. In Zichermann and Cunningham (2011), authors found that the average player is at the same time an 80% socializer, 50% explorer, 40% achiever, and 20% killer.

2.4 Game Design

In Zichermann and Cunningham (2011), authors take into account the Mechanics, Dynamics, Aesthetics (MDA) framework. The mechanics define the functioning of the system, dynamics deal with player's interaction, and aesthetics is about the player's feelings during interaction. Authors identify twelve things people like and for each of them, a set of game mechanisms that can be used to create player engagement. Some of the latter mechanisms are points, levels, leaderboards, badges, challenges/quests, onboarding, and engagement loops. In "Gamification 101: An Introduction to the Use of Game Dynamics to Influence Behavior" (2010) , instead, mechanisms and dynamics are considered, by bringing the aesthetics into dynamics. Game mechanics are points, levels, challenges, virtual goods and spaces, leaderboards, gifts and charity while game dynamics are reward, status, achievement, self-expression, competition, altruism.

2.5 Gamification in Crowdsourcing

The concept of bringing game mechanisms into crowdsourcing applications appeared for the first time under the name "Games With A Purpose" (GWAP) (Von Ahn and Dabbish, 2008). That concept was designed in attempt to apply gaming practices to crowdsourcing tasks (often boring) that cannot be automated by computers, like labeling a random image found in the web. The authors of GWAP believe that the gamification approach to crowdsourcing is motivated by three factors: (1) an increasing proportion of the world's population has gained access to the internet; (2) certain tasks are difficult for machines but easy for humans; and (3) people spend a lot of time playing games on computers. An extensive review on the application of gamification to crowdsourcing has appeared in Morschheuser et al. (2017). A question faced in Morschheuser, Hamari, and Maedche (2018) is whether cooperation or competition among individuals contribute more to crowdsourcing participation: the results indicate that cooperative approaches increase users' willingness to participate in crowdsourcing and that competition between teams leads to greater enjoyment and usefulness of the system. A location-based game (LBG) is a game that exploits players' position as a fundamental game mechanism (Kiefer, Matyas, and Schlieder, 2008). Location-based games as an approach to VGI have been shown to be successful in motivating non-expert users to collect and tag geospatial data. In Schlieder, Kiefer, and Matyas (2006), authors consider an LBG to be challenging if it requires both the players' acting and reasoning skills. CityExplorer (Matyas et al., 2008) was the first LBG designed with the primary goal to produce geospatial data that is useful for non-gaming applications like a location-based service.

3 A GAMIFICATION FRAMEWORK FOR GEOGRAPHIC INFORMATION

In this section, we introduce the main components of the gamification framework and we discuss the relations among human needs, game mechanisms and player types.

3.1 Model Definition

Users, data, and tasks are the components that characterize any VGI application and make it different from other applications (Bucher et al., 2016; Capineri, 2016). The users are volunteer people who offer their time and skills to enter geographic data and perform geo-data related tasks, such as gathering, validation, and integration: as any human being, they need to be encouraged for their endeavors. VGI users are distinguished by the human needs they tend to satisfy and by their commitment or level of contribution. Human needs are mapped to game mechanisms and *player* types. The level of contribution is taken into account by rewarding game mechanisms, such as scores and leaderboards, and influence the player's profile. Geographic data is a collection of information that can describe objects and things with relation to space: it is stored as geometric data types like point, line, and polygon and is usually associated to descriptive data like names, short descriptions, categories, and multimedia data such as pictures; geographic data are visualized on a Map. Regarding the tasks that can be applied to geographic data, we identify the following four tasks:

- Geo-data gathering task: it includes the insertion, modification, and deletion of geo-data, and the insertion of missing information to an element (e.g., geo-reference) (Antoniou, Capineri, and Haklay, 2018);
- Geo-data validation task: it includes the verification of data truthfulness after their creation or updating by leaving a feedback (discussions, comments, judgments, truthfulness level) (Fonte et al., 2015);

- Geo-data fixing task: it includes wrong data correction and the modification of a specific information about geo-data (Mooney et al., 2016);
- Geo-data integration task: it includes the identification of redundant data and the merging into a single valid data set (Sester et al., 2014).

The game mechanisms that we introduced are scores, badges, virtual goods, bonus, avatar, levels, leaderboards, friending, ownership, and votes. Further, we identify a player and a game-board. According to Bartle (1996), the player can be one in the set: Achiever, Explorer, Socializer, and Killer. A conceptual representation of the model is shown in Figure 1. The figure shows the mapping between a VGI application (top part) to the corresponding gamified application (bottom part). The main components of the VGI application are the User, the Geo-data, and the Tasks. We also distinguish the storage of geo-data from the Map that is used to display the data.

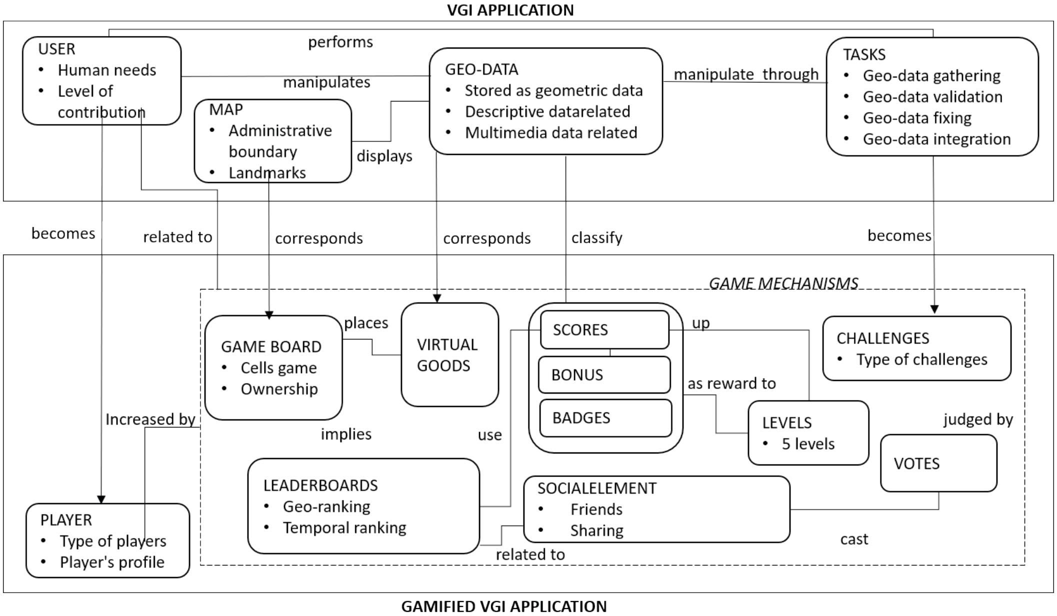


Figure 1: Conceptual model for the gamification of VGI applications.

Table 1: Relations among Human needs, Game mechanisms, and Player types.

Human needs	Game mechanisms	Player types
Self-expression	Avatar, virtual goods	Socializers
Social recognition	Friends, sharing	Socializers
Competition	Leaderboards	Achievers/Killers
Progression	Levels	Achievers/Killers
Reward	Points, badges, bonus	Achievers/Killers
Ownership	Virtual goods	Achievers/Killers
Cheating	Voting others	Killers
Achievement	Challenges	Explorers
Curiosity	Random elements, locked elements	Explorers

The gamified application is obtained with the transformations illustrated in Figure 1: users correspond to *Players*, tasks are transformed into *Challenges* and geographic data are associated to *Virtual goods*. The type of information that describes the Geographic data is connected to earning a *Score* and *Badges*, which serve to *Level* up and climb *Leaderboards* (geographical ranking and temporal ranking). A *bonus* can be given in special cases, such as when a geo-data gathering task is completed or daily bonuses when the user is logging in at least once a day. Furthermore, the map where geographic data is viewed corresponds to a *Game board*: various features displayed on the map could be the subject of gamification; for example, administrative boundaries can be used as cells to permit players to conquer territories when they are owners of the higher number of virtual goods in that area; landmarks, such as buildings, can be used to trigger user attention and implement ownership. Other mechanisms that are visualized in the map, such as *Social interaction* among users takes place by adding friends and by sharing their own experiences. A player could develop negative behaviors, such as the continuous modification of a piece of information to increase the score. *Votes* are introduced as a means to be judged by other players to push the user to operate correctly.

3.2 Relations among Human Needs, Game Mechanisms and Player Types

As we can see in the model of Figure 1, the users become players in the gamification and are related to game mechanisms, which in various ways satisfy user needs. The players' profiles are increased by various game mechanisms as well. In this subsection, we point out the human needs that we took into consideration in our model and how they are connected to the game mechanisms that we implemented based on player's type. The human needs that we consider are Self-expression, Social recognition, Competition, Progression, Reward, Ownership, Cheating, Achievement, and Curiosity. Such a list of human needs has been synthesized from various empirical studies on intrinsic motivations and need satisfaction (Hanus and Fox, 2015; Mekler et al., 2017; van Roy and Zaman, 2019; Xi and Hamari, 2019). We map each specific human need to particular game mechanisms that we chose to implement in our model. In Table 1, we present the correspondence between human needs and the game mechanisms, as well as the player types such mechanisms are mainly intended for.

Specifically, self-expression is an exhibition of one's own personality, whose appearance can be facilitated by avatars and virtual goods (Goel and Mousavidin, 2007). Social recognition can be defined as the necessity of being part of a group (Hsu et al., 2007). The wish to interact with other people is the stronger need that drives a player (Zichermann and Cunningham, 2011) and is important to build a community, encourage competition and collaboration. This need is linked with mechanisms such as friending, sharing experiences, gifting, and group quest. Competition is the basis for most of humanity's progress and evolution, even if different personality types have different feelings about competition (Morschheuser et al., 2018). Competition can be triggered by the mechanism of leaderboards (de-Marcos, Garcia-Lopez, and Garcia-Cabot, 2016). Progression can be implemented by the mechanism of levels (Richter, Raban, and Rafaeli, 2015). Rewards constitute essential mechanisms of gamification (Richter et al., 2015). We suggest introducing rewards such as points, bonuses, badges or levels, progress bars, and virtual currency. Ownership relates to the dynamic of "wanting" something. It is implemented by virtual goods that can correspond to various items, depending on the context (Seaborn and Fels, 2015). Achievement desire instead, can be associated to the completion of challenges and missions (Seaborn and Fels, 2015). Cheating is an intrinsic risk in any game mechanism and should be properly taken into account in the design phase (Robson et al., 2016). Curiosity of the player can be stimulated by a variety of means, such as introducing locked items, treasure chests, and random rewards (Zuckerman and Gal-Oz, 2014).

Regarding the appeal of game mechanisms to player types, triggering self-expression and social recognition increase the number of Socializer players, which are the majority of players (Zichermann and Cunningham, 2011). Achiever players are especially motivated by reward, competition, and progress, but also Killers are increased by the same mechanisms. Explorer players instead are attracted by introducing game mechanisms such as challenges, locked elements, random elements and others. Player profiles contain more information than user profiles, such as avatar, earned rewards (points, badges, virtual goods), rank, and status. In order to involve a user in performing Tasks, they need to be encapsulated in Challenges. The latter ones can be easy, difficult, surprising, or funny. We identify three relevant types of challenges, taking inspiration from Celino et al. (2012): "creative", "quiz", and "rating". Creative challenges mean the challenges draw from a metaphor. Quiz challenges include missing information challenges or multiple-choice questions. Rating challenges ask players to rate aspects according to some scale, such as "good", "not good", "I don't know". Each challenge type can be subject to a time limit, to a competition, to a conditional lock, or to a combination of them. All challenges need to be visible on the map and linked to real geographic data, in such a way that the attention of players can focus on the conquest of a territory. The ownership of a whole area can be assigned to the player that possesses more geographical features (virtual goods) of the area. Players' motivations can increase if they can play in specific parts of the territory, such as their home town. Virtual goods, that is, geographic data can be owned by the player who gives substantial contributions to them. The mechanism of badges is linked to the earned score and specific types of badges can be set. Badges can be with milestones (e.g., stars) or without. If milestones are chosen, they can be achieved by players reaching further objectives. According to Coleman et al. (2009), contributors can be distinguished in five levels: neophyte, interested amateur, expert amateur, expert professional, and expert authority. To each level, it is possible to assign a different range of scores: typically, to the entry level a shorter range is assigned and to next levels increasing ranges are assigned. For leaderboards, we privilege geo-leaderboards that can represent the competition among players of the same geographic area. Temporal rankings might also be included to show overall best rankings and weekly or monthly rankings. An application should also include means to add someone to a list of "friends" (a mechanism called "friending"), to exchange messages, watching a friend's leaderboard or information.

4 AN ANDROID GAMIFICATION LIBRARY

In this section, we describe how the gamification framework has been transferred to a technological development. The main idea was to implement a mobile app to make it available to a large number of users and test geographic data collection. The software has been designed following the principles of the object-oriented paradigm. Therefore, we concentrated on developing reusable packages that can work on a variety of VGI applications. At the core of the software implementation, we designed a library that implements the concepts of the gamification framework of Section 3 in corresponding software classes such as *Player* and *Score*. This library, called *Gamification Library*, can be reused as a basis of any VGI application: later in Section 5, we will use the library to develop, as a specific case study, a mobile app that collects indoor spatial data in a university campus. While we developed the gamification library as an Android library, the migration to other mobile operating systems would be not difficult as well. Object-oriented design is based on the reuse of so-called design patterns, such as the Model View Controller (MVC) pattern (Gamma et al., 1994). Following this design architecture, the concepts of the gamification framework need to be split in different patterns or packages. For example, the player, its score, and leaderboards are part of the *model* package of the gamification library. Also, the packages *adapter*, *fragment*, and *view* are considered. For visualization purposes, the *view* package is included for the graphical representation of game mechanisms, such as leaderboards.

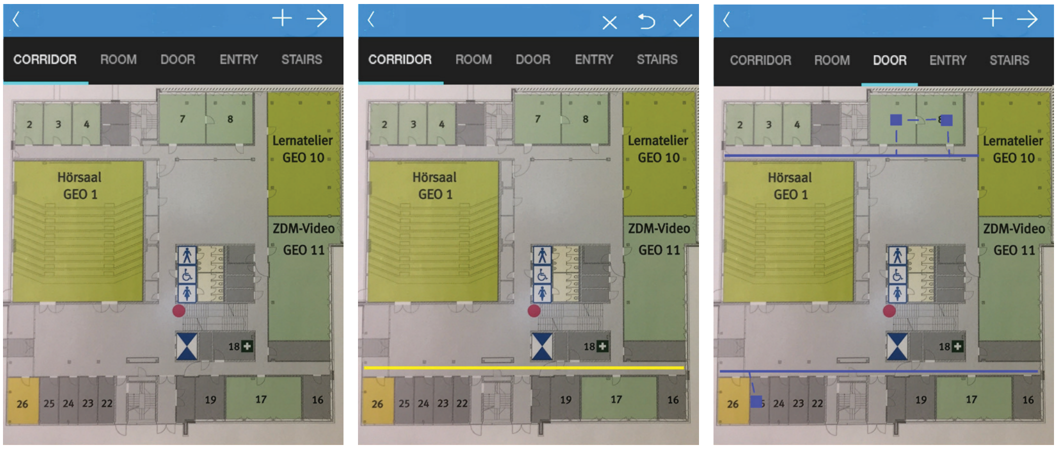
The concepts of the gamification framework to object-oriented classes was performed as follows. The player who accesses the application is modeled by the abstract class *Player*, which has the abstract method *getIdentification* and three methods to get player's score (distinguished in temporal, geographical, and geo-temporal score). The score is modeled by means of a class *Score* having multiple constructors. For the geographical score we need to model the area to which score belongs to (using the class *Area*). A ranking is modeled by the class Leaderboard that consists of many objects of the class *LeaderboardRow* depending on the number of players taking part in the ranking. Each *LeaderboardRow* object in fact is associated with a player and a score. The class *Leaderboard* has methods such as *getRankPlayer*, which returns the rank of a given player, *sortleaderboardByDescending*, which orders the ranking based on a decreasing score, and *setNumberPlayerVisibles* to display only a certain number of players. The levels of the application are modeled by the class *LevelSystem* which consists of more objects *Level*. A level is in fact modeled by the *Level* class that consists of an upper bound score, a lower bound score and a generic object Status. A level is not necessarily identified by an integer, but it could be of any type (e.g., a string for beginner, intermediate, and so on). Each player also has an associated level. The ownership of any feature that can be conquered by the player is modeled by a generic *Ownership* class.

5 CASE STUDY: GAMIFYING THE CAMPUSMAPPER APP

This section presents a case study where we apply the gamification framework of Section 3 to an existing VGI application (namely, CampusMapper). The implementation makes use of the gamification library introduced in Section 4. We first briefly describe the application CampusMapper in Section 5.1, then we describe how the gamification framework is applied to obtain the gamified version of CampusMapper in Section 5.2, and finally we describe the gamified application CampusMapper-Gamified in Section 5.3.

5.1 How CampusMapper works

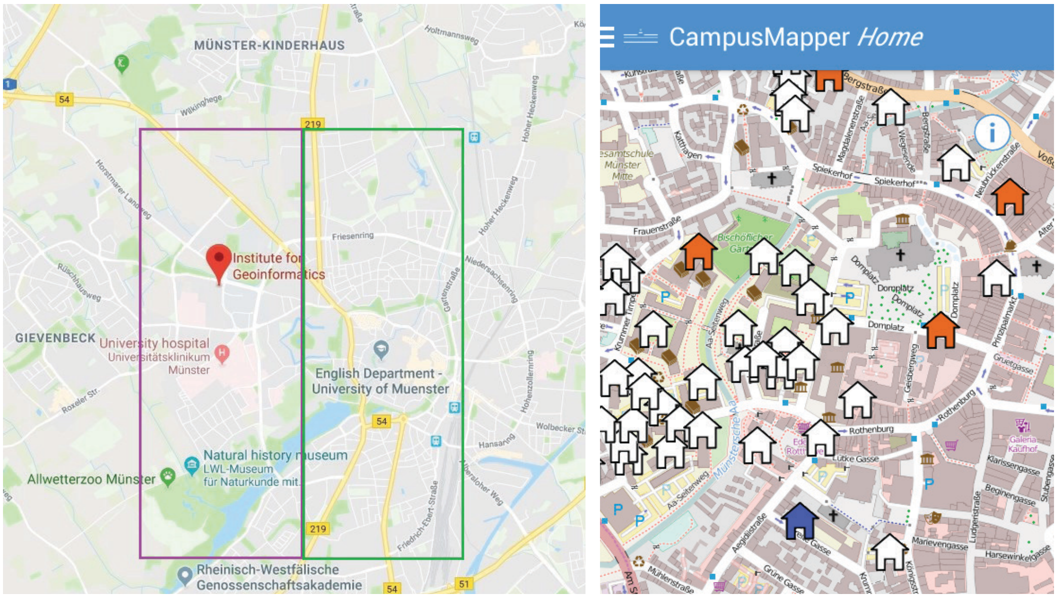
CampusMapper is a mobile application for collecting indoor data at the University of Münster with the purpose of setting up an indoor navigation system. The application is used to obtain a digitized map of university indoor spaces, made up of corridors, doors, elevators, rooms, and other features. Initially, the app allows the user to start a new floor or edit an existing one. The current building needs to be selected from a list of university buildings. When the building is selected, the floor number should be entered. Before starting data collection, a base map of the floor should be entered, either from the gallery or from the mobile camera. Such a base map is a picture of public escape plan that is available at each floor. The CampusMapper app allows cropping the image and then the mapping activity can take place. Figure 2a shows the base image of a floor that has been selected. In current implementation, we did not consider the automatic positioning of the user; therefore, the user needs to explore the building and be able to evaluate his/her current position in the map. At this point, the user walks through the floor and starts the input of map elements by drawing simple graphics such as lines and points directly on the mobile phone. The input of map elements is subdivided in five steps (corridors, rooms, doors, entries, stairs) and each step can be reached by clicking the arrow icon on the top-right. The first step consists in the creation of corridors, by drawing lines on the screen. Figure 2b shows the drawing of a corridor as a yellow line. A corridor may consist of more than one line. All new lines will be connected automatically to the nearest line of the current corridor. There might be multiple corridors in one floor plan.



(a) (b) (c)

Figure 2: (a) Blank map in CampusMapper; (b) Corridor creation in CampusMapper; (c) Rooms or corridors can be connected to each other by doors.

Rooms are represented as points and the user needs to enter the room name or number. It is possible to automatically create a door from the current room to the nearest corridor. Doors are used as a connection between two rooms, a connection between a room and a corridor or a connection between two corridors. Doors are represented as dotted lines in Figure 2c. The term "entry" refers both to a normal entrance connecting indoor and outdoor space and a connection between two floor plans of the same floor level. The last step is adding stairs. The concept of stairs used in the context of this application may be better understood using the term vertical connection, since this step includes not only creating stairs but also elevators. For storage, all elements are saved as geometric types (e.g., Point or Line) with a reference system based on the internal coordinates of the mobile device's screen and semantic information coming from an Open Linked-Data database called LODUM (http://lodum.de/).



(a) (b)

Figure 3: (a) Münster left area (colored in violet) and Münster center area (colored in green); (b) CampusMapperGamified home screen shows the Münster city map and 308 buildings of its University.

5.2 Applying the Framework to the CampusMapper App

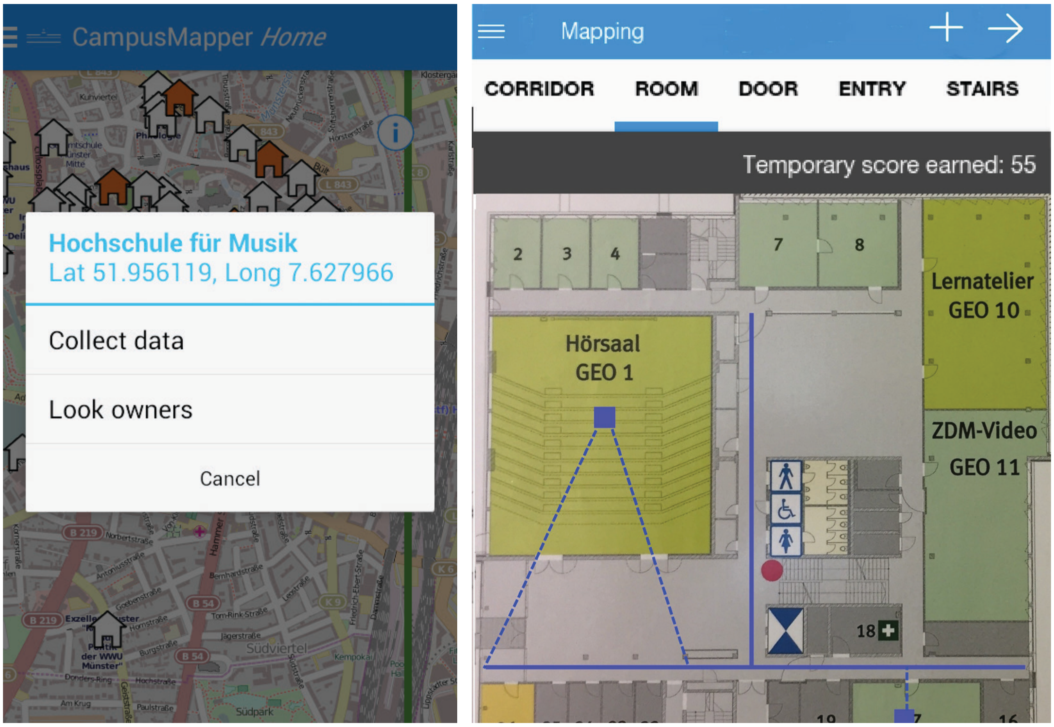
The first step in applying the gamification framework is the identification of the three main components as previously specified in Section 3, that is, who the users are, how the geo-data is structured, and which tasks users must perform. The second step is about the selection of the game mechanisms to integrate into the application, which are chosen by considering the users' intrinsic motivations. The third step is to adapt the application in such a way gamification can be introduced. Users of the CampusMapper app are people of the University of Münster (students, professors, trainees). The main task that the application is performing is to collect indoor data. Simple shapes have been chosen for geometric data to facilitate data input in a smartphone touchscreen: a corridor is digitized as a line, a room as a point (e.g., its center) and described by a name and people inside it, a door is digitized as a line connecting two rooms, the main entry to the floor is a point, and stairs/elevator are also represented as a point. Regarding game mechanisms, we opted to introduce rewards such as score and bonuses. The score assigned to the player varies based on the geometric features that have been added, making the hypothesis that introducing a line requires more effort than introducing a point: the score is increased by five for each point feature and by ten for each line feature. Besides, the score is increased by two for the name of the room, by one for each person in the room, and by one if the user connects stairs to other stairs. A bonus of ten can be awarded to a user that inserted at least a feature for each type. Then, we identified the five levels and calibrated the score for each level, by considering the number of buildings in the university and the number of floors of all buildings. We also integrated temporal leaderboards for all the period and for last 15 days and a geographic leaderboard showing players' scores for two areas in Münster: the center of Münster and its left area which contains more than a half of all buildings (Figure 3a). Besides, we made possible that a user can conquer a building by earning the highest score for that building. Further, to make the ownership more interesting, we considered also the floor owners, which are the players that got the higher score for those floors. In this way, we subdivided owners in two levels.

5.3 The design of CampusMapperGamified App

The result of gamification of CampusMapper has been called CampusMapperGamified. Starting the application, the user is presented with a map of the town where all the buildings of the university (308) are highlighted (Figure 3b). White icons represent a building with no data collection yet. Blue icons represent buildings for which the player has currently the highest score (and therefore owns it). Orange icons represent buildings owned by other players. When a player clicks on a white building, the option to collect data appears, while for orange and blue buildings two options are given, either "Collect data" or "Look owners" (Figure 4a). The dialog box's title shows the coordinates and name of the building. The option "Look owners" gives access to a list of owners of the building (there might be owners of different level). The option "Collect data" would start the data collection process as in the CampusMapper app. During data collection, in the moment a player correctly introduces a new geometric feature, a popup on the screen informs the player of the earned score. Adding a feature increases the green score of the player, while removing a feature increases the red score of the player. For example, in Figure 4b, after collecting several corridors and rooms, the temporary score earned by the player is shown. Before the session is concluded, the scores are deemed to be temporary and, only after completing the data uploading to the server, the new score is assigned to the player and a check is performed whether bonuses can be added as well. The client/server dialog implies a quite heavy data exchange both to retrieve the list of buildings from the database and to store newly mapped features and players' scores. Buildings retrieval is onerous because two SPARQL queries need to be performed: one to LODUM triple store to retrieve all buildings and another one to "indoormapping" repository to retrieve those players who are building owners. Leaderboards display is also onerous because we need to perform similar queries to retrieve building and temporal and geographical player scores relative to areas considered. To make spatial queries, *geo* and *wgs84* vocabulary have been used (PREFIX omgeo: <http://www.ontotext.com/owlim/geo#> and PREFIX geo: <http://www.w3.org/2003/01/geo/ wgs84_pos#>); in particular, the function *omgeo:within(lat1 lon1 lat2 lon2)* has been used to get all buildings that have a centroid falling in the center or left area. In future work, the app could be extended by using other spatial operators or spatial reasoning tools to be more efficient (Billen and Clementini, 2005; Fogliaroni and Clementini, 2014; Russo, Zlatanova, and Clementini, 2014; Tarquini and Clementini, 2008).

6 EVALUATING CAMPUSMAPPERGAMIFIED

We tested the CampusMapperGamified application with the help of end-users that performed a series of mapping activities to collect data on indoor environments of the University of Münster. Among the many aspects in user interaction that can be evaluated to compare the two apps (the original CampusMapper and its gamified version), we concentrated our attention on the applicability of the gaming operations, e.g., "Is it possible for a user to conquer buildings owned by other users?", and to understand the trustworthiness of the mapping operations performed by users, e.g., whether gaming mechanisms encourage users to cheat. Trustworthiness is a measure often used in VGI to assess data quality (Fogliaroni, D'Antonio, and Clementini, 2018), since the irresponsible behavior of some volunteers could jeopardize the work of an entire community.



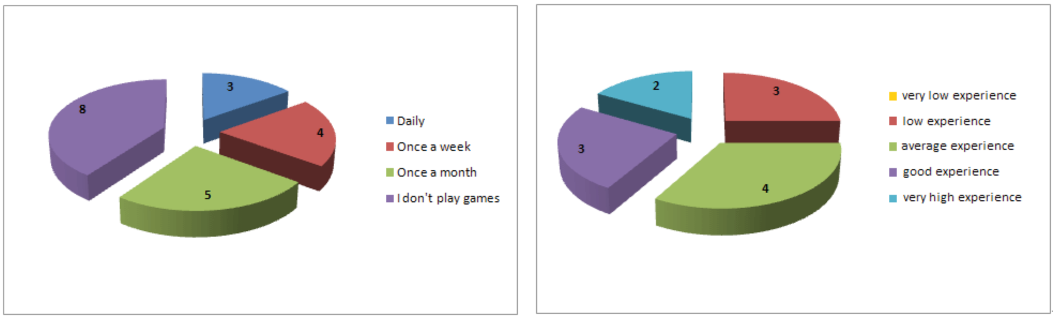
(a) (b)

Figure 4: (a) Dialog appearing after clicking on the "Hochschule für Musik" orange building; (b) Earning score by introducing geometric features.

The experiment was prepared with a list of four tasks, corresponding to the actual operations the player was requested to perform with the application. Two questionnaires were handed to players, one about personal information and background with gamified mobile applications and another one about questions concerning the performed operations. The tasks have been chosen to assess the gaming experience of the users, especially with respect to the conquering of buildings, the gaining of scores, and the climbing of leaderboards. The two questionnaires are included in Appendix 1. Specifically, the task list indicated the following actions to perform:

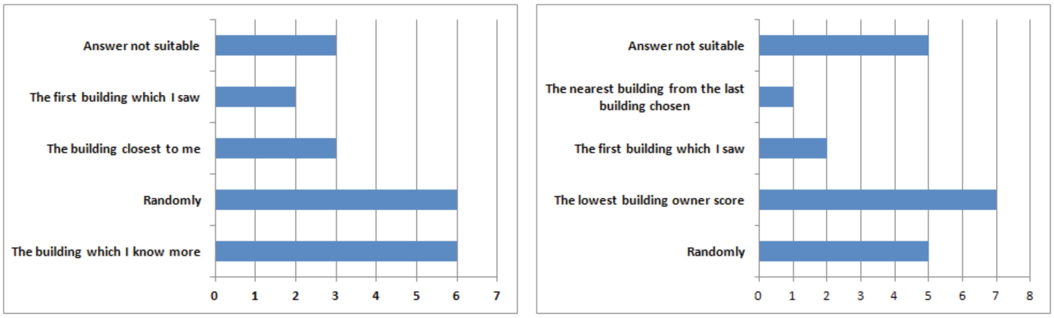
1. conquer a building chosen by the user that is not yet owned by someone else (white building);
2. conquer a building chosen by the user that is already owned by someone else (orange building);
3. earn one of the top three positions in a free-choice leaderboard;
4. reach the second level by exceeding 300 points.

The participants in the evaluation were 20 students of the University of Münster. Participants used their own Android device, where the CampusMapperGamified app was installed, and carried out the required tasks. The average time spent by each player to play with the game was about 15 minutes. By analyzing the answers of the first questionnaire, it was found that 14 users were between 20 and 30 years old and 6 were between 31 and 40. Regarding gender, they were 12 males and 8 females. To the question about how often users played computer games, the answers were distributed as shown in Figure 5a. 12 out 20 users had previous experience in gamified applications: in this subgroup, they rated themselves in the range from low experience to very high experience (Figure 5b).



(a) (b)

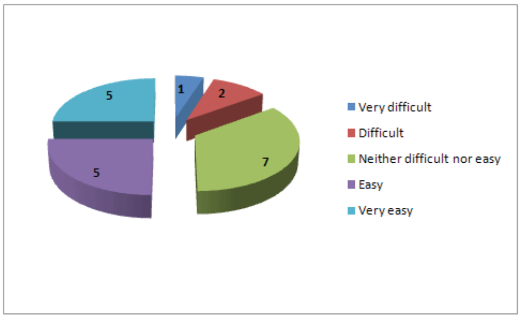
Figure 5: (a) How often CampusMapperGamified test participants use to play games on pc/tablet/ smartphone; (b) How CampusMapperGamified test participants rate themselves expert in the use of gamified applications (only participants with some previous experience could answer this question).



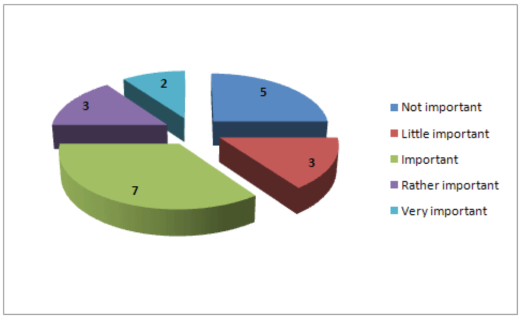
(a) (b)

Figure 6: (a) How CampusMapperGamified test participants choose the building to be mapped for task 1; (b) the same for task 2.

From the results of the second questionnaire, all players completed task 1, 15 of them completed tasks 2 and 3, and 16 of them completed task 4. Concerning tasks 2 and 3, it is worth to point out that four of the users that did not complete the tasks were users that did not have previous experience in gamified applications. Concerning task 4, three players that did not complete the task were inexperienced in gaming techniques as well. To the question "How did you choose the building to be mapped for task 1?", the responses have been classified as in Figure 6a. The majority of participants either chose the building randomly or the one they knew more. To the question "How did you choose the building to be mapped for task 2?", responses were classified as shown in Figure 6b. The prevalent responses were either choosing the building randomly or choosing the building with the lowest building owner's score. For most participants, it was not difficult to identify buildings on the map (Figure 7a) even if they all agree that they would have been facilitated by having available a button "Locate me" that places them on the map. Furthermore, from the results we note that the presence of geographic leaderboards has rather influenced the behavior of users in the choice of the building to be mapped (Figure 7b).



(a)



(b)

Figure 7: (a) How CampusMapperGamified test participants answer to the question: "Regarding tasks 1 and 2, was it difficult for you to identify the target building on the map?; (b) answer to the question "How important were the geographical leaderboards for your choice of the buildings to map?".

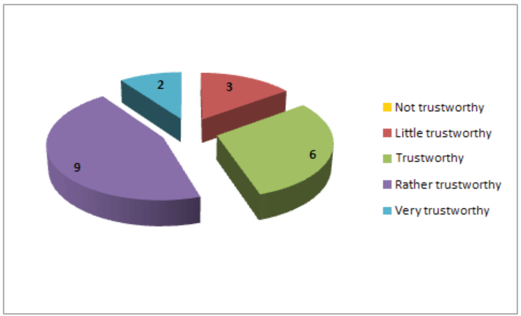


Figure 8: Answer of the participants to the question: "How trustworthy was your mapping of reality?".

Regarding trustworthiness of the mapping actions performed, the answer of participants ranges from little trustworthy to very trustworthy (Figure 8), even though in the following question half of them admit having entered on purpose false information during the mapping. The reason of this behavior was that they did not know the details to be entered (7 participants) or they cheated to increase their score (3 participants).As we said, 15 participants completed the task 3 ("Earn one of the top 3 positions in a free-choice leaderboard") and 16 participants completed the task 4 ("Reach the second level by exceeding the score of 300"). The self-evaluation about how difficult the completion of such tasks was is illustrated in Figure 9: the answers are distributed along the range. Regarding the choice of the leaderboard to climb in task 3, the results are illustrated in Figure 10. The most significant answers are those of participants that have chosen the leaderboard with players having less score: such a choice is the smartest because the leaderboard is easier to climb. We notice that this choice was made by experienced gamers. Another group of participants chose the leaderboard where they were already: this choice appeared to be convenient since they already had a good position in the leaderboard. Less experienced users operated other choices.

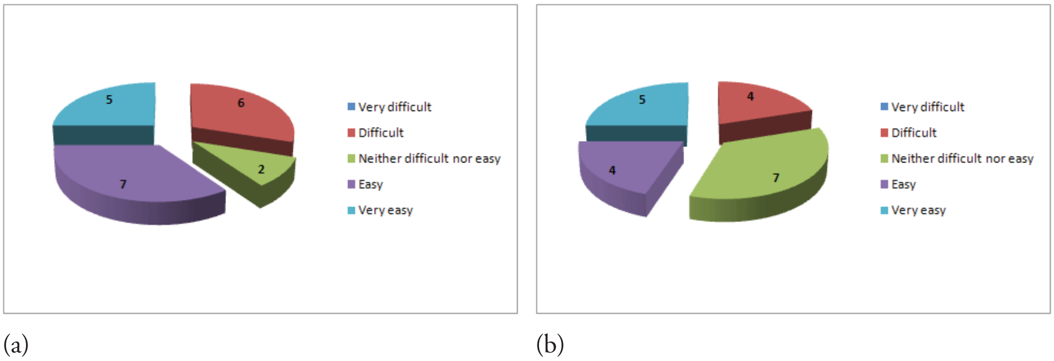


Figure 9: (a) Answer of the participants to the question about how difficult the completion of task 3 was; (b) the same for task 4.

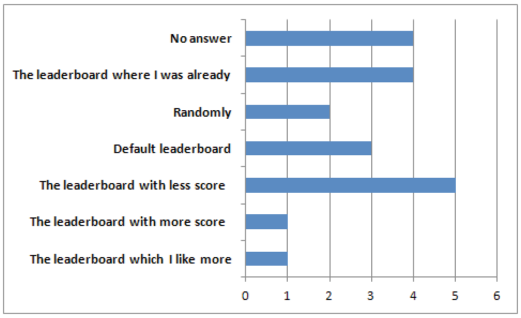


Figure 10: Motivations for choosing the leaderboard to perform task 3.

Overall, we noticed that users that did not have previous experience in gamified applications were not able to complete the tasks and made the wrong choices in the experiment, such as they chose the less convenient building in task 2 and the less convenient leaderboard in task 3. This result is positive with regard to the issue of the applicability of gamification to the indoor mapping context, because experienced users in gaming were able to complete the assigned tasks without difficulty. With regard to trustworthiness of the mapping, the majority of participants behaved correctly and only three of them cheated on purpose to increase their scores. The fact that other seven participants introduced wrong information is because they did not know enough about the floor to be mapped: a factor that is external to the gamification approach.

7 CONCLUSIONS

Crowdsourcing has revolutionized the world of geographic information, which in the two last decades has shifted from legacy data to freely available data. Spatial and location-based applications have strengthened their importance in our daily life. One issue in VGI is keeping alive the interest of citizens in contributing to the update and development of geographic systems. Gamification is a viable solution to such a problem, by leveraging users' intrinsic motivations through gaming mechanisms. In this paper, we proposed a conceptual gamification framework that is applicable to any crowdsourcing project about geographic information. The conceptual framework identifies the main concepts that can be identified in the VGI application and how they need to be mapped to well-known gamification concepts.

At the implementation level, it is important to define a software architecture that allows the developers to easily introduce the gamification framework in their applications. Concentrating on mobile applications, we designed a gamification library that can be reused for deploying various VGI apps that share the same principles. The gamification library is a software component that implements the concepts of the gamification framework. When designing a particular app, the developer can import the gamification library in the project, then the developer chooses which objects of the application should be the players, what are the objects that can be owned by the players, how scores and leaderboards are organized, and so on. As a case study, we implemented a gamified version of an app called CampusMapper, whose scope is the spatial data collection of geometric features in indoor spaces. We showed how the gamification library has been used and which gaming mechanisms are present in the case study. We performed an evaluation of the gamification framework by conducting end-user experiments with students of University of Münster, with particular emphasis on the applicability of the gaming operations in VGI and the trustworthiness of the mapping operations performed by users.

We believe that the application of gamification to VGI is a very promising approach to foster motivations of volunteers. While VGI applications already motivate participants in terms of self-expression and social recognition, the introduction of game mechanisms leverages other human needs such as competition and rewards. The development of the conceptual framework has shown that the components of VGI applications are easily mapped to gamification techniques and that, once these are standardized in a gamification library, the development of a new VGI app in a given context follows an easy pattern. While the experiments returned some general evidence on the usefulness of the approach, further experiments are needed to evaluate the approach in other settings, e.g., with a more significant spatial data collection process or in a long-term deployment study.

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APPENDIX 1

Questionnaire 1

Indoor mapping by using gamification - Study overview

The purpose of this experiment is to obtain information about user experience in a newly developed App, called CampusMapperGamified. This App is used to collect mapping data of the interior of buildings at University of Münster. The App has been designed with a "gaming" paradigm. If at any time you feel unable to continue participating in the experiment (for whatever reason), please inform us and you will be released immediately. We are collecting information from about 20 participants: our study will greatly benefit from your help.

You will first be asked to fill out a brief questionnaire at the beginning of the test. This questionnaire will ask general questions about your background in gamified applications. Then, you will be asked to perform four tasks using the mobile application on your device. You may ask questions about the test at any time during the experiment. At the end of the tasks, you will be asked to fill out another questionnaire about the test.

The questionnaire is anonymous.

The duration of the test is not predetermined but it is decided by yourself.

Indoor mapping by using gamification - Information about yourself

1. Your age.

[ ] 20-30 [ ] 31-40 [ ] 41-50 [ ] 51 and older

2. Your gender.

[ ] male [ ] female

3. How often do you play games using computer/tablet/smartphone?

[ ] daily [ ] once a week [ ] once a month [ ] I do not play games

4. Have you ever used gamified applications where you receive score, badges or any other kind of reward for your interaction with those applications? (e.g. stackoverow.com, tripadvisor.com, foursquare.com, etc.)

[ ] yes [ ] no (if your answer is no, please finish the questionnaire here)

5. How would you rate your expertise as a user of gamified applications?

[ ] very low experience [ ] low experience [ ] average experience [ ] good experience [ ] very high experience

Thank you very much for your help.

Please turn this page and have a look at the four tasks you have to complete.

Tasks List

1. Conquer a building that you know and that is not owned yet by someone else (white building)
2. Conquer a building that you know and that is already owned by others (orange building)
3. Earn one of the top 3 positions in a free-choice leaderboard
4. Reach the second level by exceeding the score of 300

Questionnaire 2

Indoor mapping by using gamification - Your thoughts

1. Were you able to complete task 1?

[ ] yes [ ] no

2. How did you choose the building to be mapped for task 1? ....

3. Were you able to complete task 2?

[ ] yes [ ] no

4. How did you choose the building to be mapped for task 2? ....

5. Regarding the tasks 1 and 2, was it difficult for you to identify the target building on the map?

1. Very difficult 2. 3. 4. 5. Very easy

6. Would it be easier to find a building on the map if your own position were shown on the map as well?

1. Very difficult 2. 3. 4. 5. Very easy

7. How important were the geographical leaderboards for your choice of the buildings to map?

1. Not important 2. 3. 4. 5. Very important

8. How trustworthy was your mapping of reality?

1. Not trustworthy at all 2. 3. 4. 5. Very trustworthy

9. Did you on purpose enter false information during the mapping?

[ ] yes [ ] no

10. If yes, why?

[ ] to get more points [ ] didn't know information [ ] other:............................

11. Were you able to complete task 3?

[ ] yes [ ] no

12. How difficult was the completion of task 3?

1. Very difficult 2. 3. 4. 5. Very easy

13. How did you choose the leaderboard to climb? ....
....

14. Were you able to complete task 4?

[ ] yes [ ] no

15. How difficult was the completion of task 4?

1. Very difficult 2. 3. 4. 5. Very easy

Thank you very much for your help.