Invited Paper

# Gamification Mechanism for Enhancing a Participatory Urban Sensing: Survey and Practical Results

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**Abstract:** This paper investigates gamification mechanisms and their application for promoting participatory urban sensing. Participatory sensing, which utilizes user smartphones as sensors, is focused on as an effective and economical sensing mechanism for wide areas. However, countinuing to motivate many participants for a long time is difficult. In addition, monetary incentives are limited generally. To solve these problems, gamification mechanisms are considered one promising technique because they have the potential to suppress monetary incentives by maintaining the motivation of participants. In addition to a general survey, we introduce our past practical research results on gamified participatory urban sensing.

**Keywords:** gamification, participatory sensing, opportunistic sensing, urban sensing, incentive, survey

## 1. Introduction

Participatory urban sensing, which is a technique for crowdsourcing a city by its citizens, has been a popular research topic and an actual application because the popularity of smartphones with various sensors and wireless networks continues to increase.

The concept of participatory sensing, fundamental architecture, and example applications was proposed in 2006 [1], [2]. Since then, various related researches and actual applications have been published [3], [4], [5], [6], [7].

Several important issues are necessary for accelerating participatory sensing. The first issue is the design of an incentive mechanism. Many commercial applications of participatory sensing such as Gigwalk [8] express advertising statements like "Make money with your iPhone," suggesting that monetary incentives are required to obtain participants. A method to minimize monetary incentives without decreasing the number of participants is a critical topic in this field. Many methods have been proposed and summarized [9], [10].

The second key issue is a method that maintains the high motivation of participants who often stop contributing for various reasons. Without incentives, maintaining motivation is particularly difficult. In our experience [11], although we successfully got 200 participants for our illuminance sensing application, the number of actual participants decreased drastically after several weeks.

The remaining key issues are the accuracy of sensed data collected by participants and smartphones as well as a method to protect the privacy of participants [12], [13], [14]. However, these issues are beyond the scope of this paper.

Apart from "sensing," some examples exist that gathered many participants without monetary incentives. Wikipedia [15] is one of the best examples. About five million English articles have already been edited [*1] by more than 48 million authors [*2]. Another example is the Open Source Software (OSS) paradigm. In the past, the source code of commercial software was considered secret information and a company's assets. However, the source code of such critical software as Android, Firefox, MySQL, Apache, and GIMP has been made released to the public. Like Wikipedia, many programmers develop software without any direct monetary incentive.

How are Wikipedia and OSS participants motivated? Answers to that important research topic has been addressed in social science and many related papers have been published [16], [17], [18], [19], [20], [21], [22], [23]. For example, Oded Nov [20] conducted a web-based survey of 151 Wikipedians and found that the top five motivations for editing Wikipedia are Fun, Ideology, Values, Understanding, and Enhancement. Values means that the authors have the opportunity to improve their value against the edited articles. Also in OSS, Values are the most important motivation since the contribution gains respect from others [16].

We address methods to add these motivations to participatory sensing in this paper. We focus on the promise of "gamification" mechanisms to promote these motivations in participatory sensing. We define gamification as a technique that introduces various positive effects of games into non-game systems [24], [25], [26]. In 2011, analysts predicted [27] that more than 50% of all companies will introduce gamification into their business processes. Actually, gamification has already been adopted in social network systems, wearable (health) systems, marketing, and education.

Our research is attempting to introduce gamification, i.e., Fun and Values, into participatory sensing [6], [11]. In our first ap-

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plication [6], we reduced monetary incentives using an effect of gamification. In our second application [11], gamification encouraged participants to constantly contribute to sensing. We introduced badge and ranking systems into both applications and conducted field experiments with actual sensing tasks. Even though these researches confirmed the positive effect of gamification, we also identified some difficulties.

In this paper, we review our past research results in addition to a general investigation for gamification, participatory sensing, and their combinations.

## 2. Related Work

We introduce some past researches related to participatory urban sensing and gamification.

### 2.1 Participatory Urban Sensing

Participatory urban sensing is a system to collect data in urban areas from smartphones. Since 2006 [1], many papers related to this topic have been published. The major target applications are public health, urban planning, and the creation of open data. There is a similar people-centric sensing application called "opportunistic sensing" [2], in which a sensing application runs continuously in the background after cooperation is obtained. Although these approaches are different [28] in a strict sense, we regard them as a participatory urban sensing.

The most frequent target of sensing in our environment can be observed by smartphone sensors, which is the most common sensor platform for participatory sensing. For example, "noise" often becomes a collection target of participatory sensing [29], [30], [31], [32]. "Road" is one typical application that has high affinity for participatory sensing. Human movements on road [33], [34], road surfaces [35], [36], traffic jams [37], and parking congestion [38], [39] are also popular targets. Although external sensors are required for the participants, air quality [40], [41], [42] and fuel efficiency [43] and scenic roads [7] are also sensed by participatory sensing.

Most examples sense the problems or the negative information of urban areas. However, examples can be found of positive information sensing. Open Signal [44] and Cellspotting [45] collect and share the information of the signal strength of 3G/LTE wireless networks. Jiwire [46] provides the information of WiFi hotspots collected by participatory sensing.

Not only researches but also various commercial services have already been started. For example, in Waze [47] more than 50 million drivers worldwide upload their driving results, including the price of gas and the locations of speed traps. FixMyStreet [48] is another famous participatory urban sensing platform that enables citizens to report problems of urban living from their smartphones. Yelp [49] reviews such local businesses as restaurants and public places. Not only textual reviews but also images of menu items and prices are uploaded by users. This is a form of participatory sensing. Weathernews in Japan [50] utilizes participatory sensing for collecting a local and detailed weather. Any person with a Weathernews mobile application can register as a volunteer weather reporter who upload pictures of the sky. Currently, more than 8 million users are registered [50].

### 2.2 Incentive Mechanism

Two incentive mechanisms for participatory sensing have already been proposed and summarized. They classified existing incentive mechanisms for participatory sensing from different viewpoints. Hui Gao et al. [10] classified in terms of money: monetary or non-monetary. Francesco Restuccia et al. [9] classified in terms of purpose: application-specific or general-purpose. In general, monetary incentives motivate participants to reliably upload a satisfactory amount of data. However, since money is not unlimited, we need to design an appropriate monetary incentive mechanism. Weathernews [50], which we introduced above, adapts an interesting incentive strategy. If a participant reports weather or the status of disaster damage, she can get 10 to 15 points. When she has accumulated 2,000 points, she receives a special weather sensor. Since the participants obviously enjoy weather, this reward provides a quite high incentive. In addition, it is also useful for the providing company, because the accuracy of weather reports will be improved if participants utilize their special sensors.

Although an incentive mechanism is one important and interesting research field, in this paper, we only focus on non-monetary incentive mechanisms. As non-monetary incentives, ranking, comparisons and intrinsic rewards are listed [10] and regarded as the gamification components that we explain in the following section.

### 2.3 Voluntary Participation

Voluntary and non-incentive participation are attractive research fields [16], [17], [18], [19], [20], [21], [22], [23]. As we mentioned in the introduction, Wikipedia is created by hundreds of thousands of volunteer editors who have no monetary incentives. Fun, Ideology, and Values are the top three factors that motivate Wikipedians [20]. The evolution of Internet and information systems successfully visualized the contribution of each editor. Many editors started representing their knowledge on Wikipedia. In the same manner, open source software has spread. By making source code open, owners expect contributions from various programmers because this is a good opportunity to show their skills and contributions. Through these results, we anticipate possibilities to obtain volunteer participants if we prepare a place where they can display their contributions.

### 2.4 Context-aware Participation Request

A context-aware task request is the last remaining important factor for realizing effective and sustainable participatory sensing. Inappropriate tasks may degrade the sensing quality and coverage and increase monetary incentives. In addition, since a task request interrupts a participant's current action, inadequate task requests cause participant defection. Shibo He et al. [51] discussed the optimal task allocation in crowd sensing. Okoshi et al. [52] proposed a context-aware interruption mechanism. We also investigated the best timing to request tasks.

## 3. Gamification

Gamification is a concept that introduces game mechanics and game design into non-gaming systems to prompt changes in user

**Fig. 1** Piano stairs.

behavior [24], [25], [26].

Piano stairs [*3], on which a piano keyboard is drawn (**Fig. 1**), is a good example of gamification. Since users can play the piano by their feet, they used the stairs instead of the escalator. The gamified stairs successfully changed user behavior by adding a fun experience that resembled a game.

### 3.1 Components of Gamification

"The basic 16 desires" defined by psychologist Steven Reiss [53], are helpful for understanding the effect or the phenomena of gamification: Power, Curiosity, Independence, Status, Social contact, Vengeance, Honor, Idealism, Physical exercise, Romance, Family, Order, Eating, Acceptance, Tranquility, and Saving. We thought that gamification equally provides a sense of satisfaction of some of these desires, especially Power, Curiosity, Status, Saving and Acceptance. A typical method to satisfy the desires is composed of three functions: Tasks, Rewards, and Communications. We explain the details of each function in the following subsection.

**Tasks**

Tasks are different depending on the application. Some applications call them "quests" or "missions." For some tasks, a certain participant might want to achieve them faster than others. In addition, rankings or a leader board can encourage competition among participants. By preparing levels in terms of difficulty, a system can provide satisfaction to every participant. Furthermore, such limitations as deadlines can be used to adjust the strength of promotions.

In participatory sensing, a typical task is a request to sense something: taking a picture [6], recording sounds [30], recording brightness [11], and uploading a textual report [6].

**Rewards**

Typical rewards are badges, experience points, upgrades, coupons, and money. Such monetary incentives as coupons, points, and cash are the most clear and easy-to-understand rewards. However, by just showing the current and remaining experience points, players tend to keep doing what they have been doing. Furthermore, badges can generate an endowment effect [54]. By mixing rare and general items, a system can give both self-satisfaction and envy to others.

[*3] http://www.thefuntheory.com/piano-staircase


**Fig. 2** Speed camera lottery.

**Communication**

Communication means such functions as chats, arguments, avatars, and social network. These functions encourage competition among participants, provide happiness through cooperation with others, and satisfy the human need for acceptance. In addition, communication provides opportunities for inactive participants to participate again or for new participants to join.

### 3.2 Applicable Area of Gamification

In recent years, gamification has been adapted in various fields as a promising technique. In product sales and restaurant services, gamification is often used for marketing promotions. A typical scenario is that participants get a reward when they visit a certain store or restaurant. However, this is not a good example of gamification because it is merely an extension of existing games or a form of monetary incentives.

The best adapting example is a gamified speed trap that successfully solved a social problem. It is called "The Speed Camera Lottery" [*4] (**Fig. 2**), was a pilot program in Stockholm. In this experiment, a speeder has to pay speeding fines as expected. However, gamification was introduced. Drivers who observe the speed limit are entered into a lottery whose payouts were taken from the collected fines of speeders. This new approach successfully changed the behavior of drivers and reduced the average speed of 24,000 cars by 22%.

The most promising field is human health. Like participatory sensing, many people have difficulty exercising everyday even if they have set goals. Therefore, many such wearable devices as smart watches and glasses have already been released for promoting daily exercise. The Apple watch provides oral message to encourage exercise when its user sits too long. If we set our daily goal as 10,000 steps, we become eager to achieve it. Especially if we have an opponent, our competitive attitude is stimulated [55]. Such activity trackers as Nike + or Fitbit usually have a social networking function. Activity results are shown as rankings to encourage competition.

### 3.3 Problems of Gamification

Although gamification has many advantages, its weak points or limitations have been reported in past studies.

#### 3.3.1 Badge Fatigue

Although a badge mechanism is usually introduced as the

[*4] http://www.thefuntheory.com/speed-camera-lottery-0

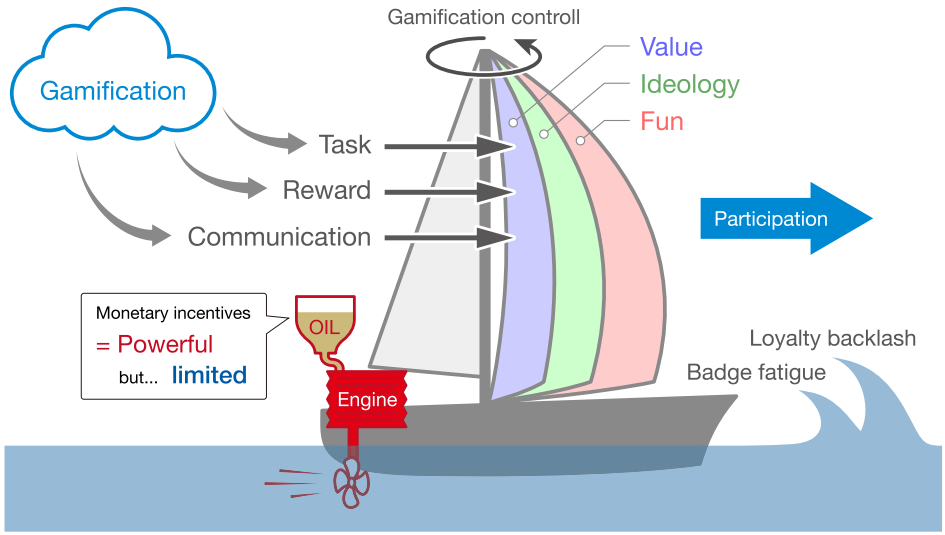


**Fig. 3** Overview of gamification mechanism in participatory sensing.

simplest gamification technique, badges are not "magic bullets." "Badge fatigue" [56] is a phenomenon in which participants start questioning why they are collecting badges. In Foursquare [57], users can become the mayor of a certain Point of Interest (POI). However, after becoming mayor, they cannot understand why they sought such a position. Such dissatisfaction is caused by the gap between the purpose of the badges and the application scenario. The adopted gamification mechanism must accompany the application's story or be completely entertaining.

#### 3.3.2 Loyalty Backlash

"Loyalty Backlash" [56] is another problem for gamification. Steve Bocska classifies the effects of gamification into three stages: Capture, Retention, and Activation. First, gamification is useful for getting new participants. However, it is hard to keep and motivate them by gamification. Loyalty backlash is the chasm between the capture and retention stages.

#### 3.3.3 Loyalty Limitation

In general, incentives, especially monetary ones, have limitations. As a typical campaign, Gap conducted a check-in-based discount in which the first 10,000 customers can get a free pair of jeans if they sign-in on Facebook at a Gap store.

This idea effectively encouraged trips to the store in the short term. However, continuously providing similar rewards is difficult. In addition, the customers who have been experienced this promotion once require even greater rewards. After the campaign stops, such customers might never return.

## 4. Gamification in Participatory Sensing

We are convinced that gamification has a particular affinity for participatory sensing. **Figure 3** shows an overview of a gamification mechanism in a participatory sensing represented as a yacht. The engine, the strongest driving force, denotes a monetary incentive. It is powerful but has a limitation: gasoline. The waves in front of the yacht show the problems of participatory sensing: badge fatigue and loyalty backslash. Gamification, which is a natural source of energy with the potential to promote participatory sensing, generates three kinds of wind: tasks, rewards, and communication. If a gamification mechanism is well designed,

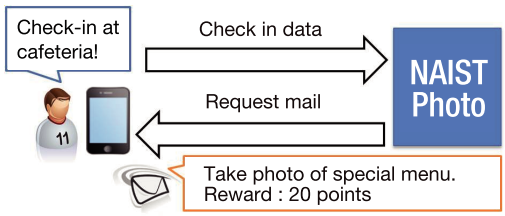


**Fig. 4** System architecture of NAIST Photo.

these three winds can generate such effects as fun, ideology, and values.

By adding game mechanics, we can expect continuous participation with higher motivation. The satisfaction given by gamification might help suppress the monetary incentives. Therefore, we introduced gamification into our two participatory sensing systems, both of which are normal participatory sensing for collecting urban information. The first application [6] collects photographic and textual explanations. The second application [11] collects the brightness of street lamps. The purpose of gamification is to reduce monetary incentives and maintain participant motivation.

### 4.1 Gamification to Reduce Monetary Insentives

The first practical result is a participatory urban sensing system, in which the administrator asks participants to report various surrounding information with photo or textual explanation (**Fig. 4**). The participants can get points (monetary incentives) as a reward like airline mileage services and obtain higher status. The purpose of gamification in this system is to reduce the reward points, i.e., monetary incentives. The tasks increase mental satisfaction by making their position in the ranking as high as possible.

Toward this goal, we introduce the following three gamification mechanisms into our system.

**Level**

All users are categorized into one of several status levels based on the points they have earned. Those with higher levels earn more points than those with lower levels even if they have com-

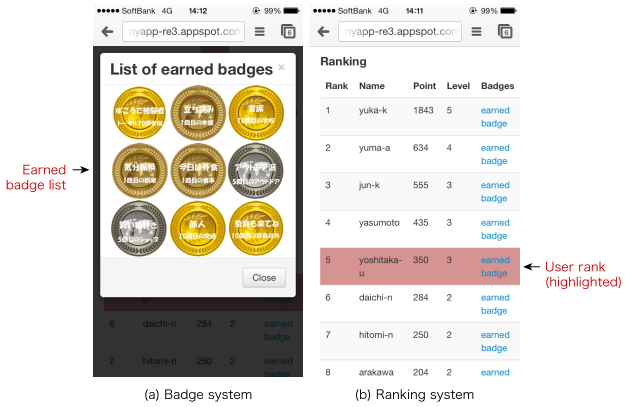


**Fig. 5** Ranking and badge UI of NAIST Photo.

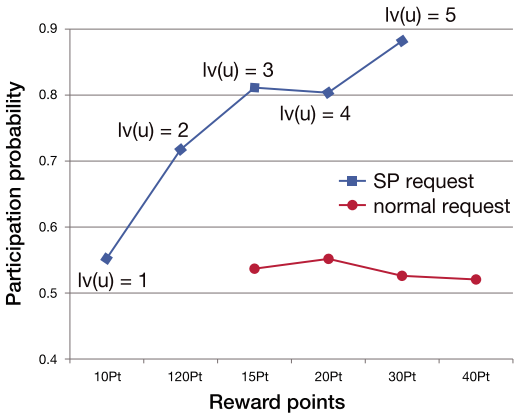


**Fig. 6** Participation probability vs. reward points.

pleted the same sensing task. By participating in numerous sensing tasks and earning many points, the users can reach the upper levels and earn more points the next time they participate in sensing tasks. Thus, users have an incentive to actively participate in sensing tasks to increase their level. This mechanism is widely adopted by airline's mileage services.

**Badges**

When a user who participated in several sensing tasks satisfies a certain condition, she obtains a badge, which represents a title of respect in the community, where the points are based on the degree of difficulty for satisfying the condition. Typical examples of the condition for obtaining badges are reaching a pre-defined number of times, or the user has participated in a pre-defined number of times at a specific city, etc. Each user can confirm her own badges and those of others through a web page (**Fig. 5** (a)). By this scheme, users are motivated to obtain badges, earn more points, and feel satisfied.

**Ranking**

In our proposed incentive mechanism, the system maintains rankings that are based on the amount of points accumulated by each user. Since this ranking can be accessed by anyone through the Internet (Fig. 5 (b)), the users are motivated to participate in sensing.

#### 4.1.1 Results

We conducted an experiment with 18 users over 30 days. **Figure 6** shows that for normal requests, the participation probability does not depend on the reward points. In contrast, the participation probability of the SP requests that are related to advancement

**Table 1** Participation probabilities for various sensing requests.

| Content of sensing request | Probability | |
|---|---|---|
| | SP | Normal |
| Take photo of landscape | 0.93 | 0.67 |
| Take photo of staying condition of laboratory | 0.91 | 0.75 |
| Take photo of parking usage | 0.89 | 0.69 |
| Take photo of shop's exterior | 0.83 | 0.63 |
| Take photo of train | 0.69 | 0.48 |
| Take photo of restaurant's limited menu | 0.56 | 0.48 |
| Take photo of congested level of facility | 0.36 | 0.5 |

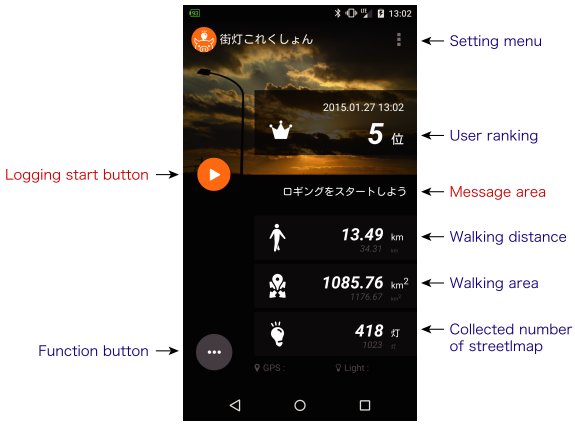


**Fig. 7** Initial application UI of Streetlamp collection.

increases as the reward points increase. Simultaneously, we confirmed that the users who were attracted to gamification tend to get more points by participating in high reward tasks.

**Table 1** shows that participation probability varies depending on the content of sensing request, because the degree of difficulty of completing a sensing task affects the participation probability. As a result, we confirmed that gamification increased the participation probability on average from 53% (without gamification) to 73%.

### 4.2 Gamification for Motivating Participants

The second practical result is a participatory urban sensing system that collects the brightness of street lamps with the light sensors of smartphones. In this study, we efficiently motivated users to participate by gamification.

We developed a smartphone application called "Streetlamp Collection" that collects the brightness and the angles of the smartphones being held and the user's location (GPS). This application runs when a user walks near a street lamp at night and aggregates the data to the server. In the early system, as a method for motivating participation, we developed a function of showing user score and user ranks (**Fig. 7**). Each user score is calculated by the walking distance, the walking area, and the number of collected streetlamps. We expected the ranks to provide a sense of competition and accomplishment for participants. However, because this application is a text-based UI, these functions failed to exert adequate effect. Therefore, we developed a new system that has many visual elements.

**Visualization on maps**

This application adopts maps to the main part of the screen. The map UI shows the collected street lamps in the past and the detected street lamps (**Fig. 8**). User can realize that this appli-

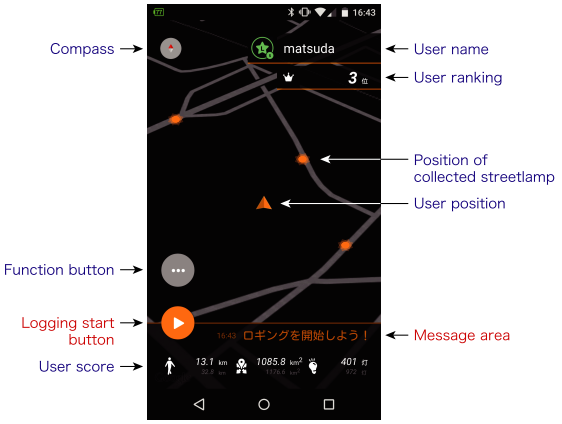


**Fig. 8** Improved UI of Streetlamp collection adding visualization on map.

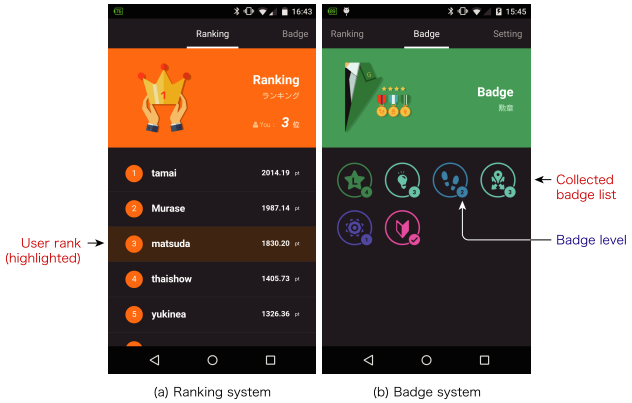


**Fig. 9** Ranking and badge UI of Streetlamp collection.

cation detects the street lamps and be satisfied of the greed of collecting.

**Ranking**

This application shows user rankings by comparing the total score (the walking distance, walking area, and the number of collected street lamps) that can be collected by user actions (**Fig. 9** (a)). Then this ranking compares user scores with your score, and users can learn the scores of the upper rank users. This application offers a challenging experience for users.

**Badges**

While accumulating scores, user can get badges if their scores exceeds particular boundaries (Fig. 9 (b)). The new badges are given in response to the status of the user scores. So the badges can maintain the motivation of users to participate.

#### 4.2.1 Result

We published our application and conducted an experiment with an unspecified number of users for a month. 101 users collected brightness data for about 301 hours without monetary incentives.

However, the number of participants decreased because this application mainly depends on the ideology, the thought like "I should figure out the dark and dangerous street for other younger citizens," of each participant. Therefore, we have to improve the gamification mechanism to generate fun and value.

## 5. Future Challenges

Finally, we mention the remaining problems and our ongoing researches.

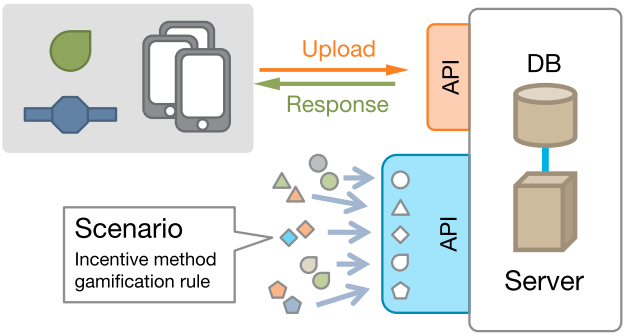


**Fig. 10** Flexible participatory sensing platform.

### 5.1 Remaining Problems

The remaining problems for enhancing participatory sensing are privacy [14], [58] and accuracy. Location information is necessary information for urban sensing. However, it causes a privacy problem; greater contributions increase the risks of privacy. This is inconsistent with the goal of encouraging participatory sensing.

The accuracy of the sensing data depends on each participant, because smartphones, which are the sensing platform, differ widely among individuals. Even though we utilize the same smartphones, each brightness sensor shows different results for identical light sources. The meta information for sensing data is subjective.

### 5.2 Participatory Sensing Platform Having Gamification Mechanism

As a sensing task, we addressed the photographic and textual explanations described in Section 4.1 and the brightness of street lamps described in Section 4.2. However, other data, including sounds, movies, temperature, and humidity will become future sensing targets. In addition, since various incentive mechanisms will be proposed, we plan to create a flexible participatory sensing platform that can deal with various sensing tasks and create incentive mechanisms including gamification (**Fig. 10**). Everyone can easily use participatory sensing with this platform by describing these elements as scenarios.

### 5.3 Experimental Study of Gamification in Social Science

"Ingress [59]," which is a location-based game with augmented reality, have gotten a lot of attention. It gives no monetary incentives, but gives badges, rank, and communication (cooperation) as same as gamified participatory urban sensing. The interesting point is that it generates unexpected positive effects to local cities because Ingress promotes the physical transfer of the game players.

In order to figure out the mechanism for adopting this phenomenon intentionally to a social science, we will start a new gamification project based on an EV-car sharing system from 2016. In our system, three electric vehicles (EV) will be shared by students. Usually, such a system requires great cost to maintain it. We are attacking this problem by introducing several gamification mechanisms by 2020. We believe that small contributions of each user can maintain the system at low cost. Small contributions that are fun is the best scenario.

## 6. Conclusion

In this paper, we investigated a basic gamification mechanism and reported our two feasibility studies of participatory sensing with gamification. Gamification is a promising technique for solving various social problems with low cost. Actually, in our first study, we successfully reduced monetary incentives by introducing gamification techniques. However, it is difficult to create successful scenarios for each system. We believe that ongoing optimization is required for maximizing the effect of gamification.

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