Civic Crowdsensing through Location-aware Virtual Monsters

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Abstract. We present a new model for encouraging people to get involved with monitoring and taking part in the life of cities. Cities could be smarter if IoT and people could serve as engaged and pro-active data resources (i.e., crowd sensing). This study tackles two challenges: methods by which the privacy of people who act as sensors/actuators can be guaranteed and methods to create a unified programming model for crowd sensors alongside other IoT functions. To achieve these goals, we introduce a new concept called Lokemon (Location Monster). Each sensing space is characterized as a personified target. Lokemon asks users to imagine themselves to be monsters associated with target spots when achieving sensing tasks. Lokemon is also expressed as a PubSub node so that the data from Lokemon can be easily accessed in the same way as data from IoT is assessed. The article explains the concept of Lokemon and its programming model. We report our evaluation of the effectiveness of Lokemon in a campus experiment that was performed for four weeks.

Keywords: Crowdsensing · Urban Computing.

1 Introduction

Computing is now widely applied in the management of urban activities and resources. The internet of things (IoT) will be ubiquitously embedded in equipment and infrastructure throughout cities. Real-time sensor data from IoT underpins the monitoring of a variety of city contexts for tasks such as day-to-day activities, which include city management, disaster management, enhancing the quality of life and encouraging economic growth. Another important resource in the cities is people. By using smartphones and wearable devices, people can act as sensors (e.g., reporting city happenings by capturing photos or counting the number of people in a line) and even actuators (e.g., picking up garbage or erasing graffiti). Since both IoT and people each have advantages, utilizing them in a complementary and transparent manner is the next paradigm for a programmable world.

We tackle following two challenges: 1) how can we persuade people to act as active sensors/actuators by reducing concerns that they will thereby sacrifice their privacy and 2) what might be suitable as a programming model/platform that would combine data from both IoT and crowd sensing. First, as several papers have already shown, crowd sensing requires incentives to motivate people to participate in sensing tasks. Also, people who report sensor data at a certain location are sometimes faced with a problem of loss of privacy - in location-aware reporting the position of the user can be identified when the report is made. It is, therefore, necessary to reduce privacy concerns to involve more people in crowd sensing. Secondly, though many platforms have been proposed and developed for IoT and crowd sensing, they are mainly designed for supporting either IoT or crowd sensing. To access data transparently and write programs effectively, any sensing method should be managed and applied in a unified way.

To solve these issues and provide a unified method for computing with both IoT and people, we introduce Lokemon, a new crowd sensing concept and platform that will embody the concept. Lokemon is short for location monster, an example of which is to be virtually placed at each point of interest (PoI) in cities. Lokemon asks users to imagine themselves to be the monsters as they perform sensing tasks. Any users currently located near the PoI identify with the Lokemon and complete tasks or answer questions from other remote users. To reduce the loss of privacy, people's actions are assigned to the Lokemon rather than being labeled with the user name or even an anonymous name. Moreover, Lokemon provides a new experience whereby the user can collect data while mimicking as a Lokemon. It is implemented by using a universal sensor network system based on the PubSub protocol [9], so that Lokemon provides an open API, which is same to that for IoT. This article presents details of the Lokemon and reports our first campus-wide experiment to evaluate its potential. In summary, the article establishes the following three developments:

- Introducing a new concept called Lokemon that achieves crowd sensing by mimicking monsters that are installed virtually at PoIs
- Providing a system architecture that integrates IoT and crowd sensing and adapting it for Lokemon
- Presenting an initial evaluation of Lokemon in a four-week experiment on campus

2 Lokemon

This section begins by describing the problems involved in crowd sensing and then introduces the concept of Lokemon as a solution.

2.1 Problems of crowdsensing

Recent progress with mobile devices such as smartphones allows people to refine and integrate their perceptive faculties as a part of sensing framework. This sensing framework, so-called crowd sensing (or participatory sensing) [1], distributes various sensing tasks (such as reporting the weather, waiting time in a queue and traffic conditions) to potential participants. By people sending a text, photo, sound data and so on, we can get subjective and qualitative data that it has been hard for physical sensors to collect hitherto, such as the mood of a place. It would make wide and high density sensing possible. However, there are some problems with existing crowd sensing systems, as follows:

1. Privacy
   Users who are participating in sensing send information to each PoI. As a result, the system knows where they are at particular times.
2. Motivation
   It is important to give an incentive because getting involved in crowd sensing is a burden on users. Without adequate incentive mechanisms, most users may not want to participate.
3. Quality of information
   It is possible to allow users to contribute information anonymously to protect their privacy. However, such information may lead to difficulties such as deterioration of quality (false information), ravage and allegations of libel and slander.

Recent researches have described many existing efforts to solve these problems [2–4]. For example, Groat et al.[2] proposed a way of protecting privacy by reconstructing reports from users using a ‘Negative Survey’ technique. In terms of incentive for participation, Sasank et al.[4] explored what kind of monetary rewards work effectively in crowd sensing. However, several limitations remain. For example, the privacy protection method works only for multiple-choice questions. Using external factors such as monetary rewards is insufficient for enhancing motivation compared to internal factors. Previous research has been tackled the problems by using “username” or “anonymous user” as the alias for the information sender. We, on the other hand, explore the possibility of solving these problems by providing an alternative: namely, mimicking location-aware virtual monsters.

2.2 Concept of Lokemon

We developed the concept of Lokemon to solve the three aforementioned issues simultaneously. The basic idea of the Lokemon is very simple: users can achieve crowd sensing as monsters, which are virtually located at each PoI. Figure 1 shows a comparison between the typical crowd sensing model and the Lokemon model. In the typical crowd sensing model, users usually use their user names (real names or pseudonyms) to send sensing data. In Lokemon model, by contrast, users send sensor data in the name of a nearby Lokemon virtually located at each sensing. We explain the detail of the Lokemon in the following scenario.

Scenario: Today is the first day of Bob's trip to Kyoto. Because of a bad case of jet lag, he wakes up at his hotel at noon and goes outside to have lunch with his smartphone in which the Lokemon application is installed. He is a great lover of ramen noodles, so he heads to a famous ramen restaurant by bus. While he

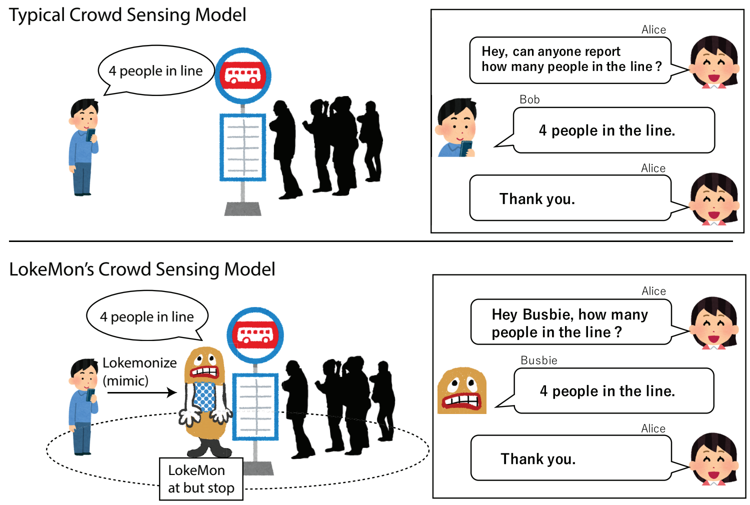

Fig. 1. Comparison of current participatory sensing model and Lokemon's sensing model. In typical crowd sensing model, a user sends sensor data by using his/her user name. In Lokemon model, a user sends sensor data by using monster name which is virtually located at a sensing spot.

waits for a bus at a bus stop, he gets notification that a new Lokemon is located at the bus stop. He opens the Lokemon application and adds the new Lokemon named Busbie to his Lokemon collection. At the same time, he finds that a user named Alice is asking Busbie how many people there are in the line. Being at the bus stop, he is able to give the information and he reports the number of people in the line identifying himself as Busbie. After a 15 minute bus ride, he finally arrives at the ramen restaurant. But the restaurant is full of people; more than 20 people are waiting outside. He gives up to eat ramen noodle, however, he collects a new Lokemon called ramen-man in the restaurant. The next day, he considers giving the ramen restaurant another try. He opens the Lokemon application and asks ramen-man about current congestion at the ramen restaurant. Ramen-man reports that there are only a few people in the restaurant, and he decides to go there to eat.

As shown in the scenario, Lokemon enables users to perform the following actions: 1) collect a Lokemon by visiting a place where it virtually lives, 2) use a Lokemon as an alias to report information near to its site, and 3) ask a question remotely of a collected Lokemon. The scenario suggests solving the three aforementioned issues as follows:

1. Privacy
   Since the users can send data in the name of Lokemon, other users cannot know who is actually reporting the data. This reduces the chance of loss of privacy.

2. Motivation
   Lokemon also uses gamification techniques such as collection, ranking or cooperation functions to motivate the users. The gamification techniques motivate the users' participation. In Lokemon, people can help others without revealing their identity. This can satisfy people's voluntary kindness for others without them being regarded as 'meddlers'. Lastly, some people get pleasure from acting as a Lokemon. These strategies may enhance the spontaneous motivation of the users to participate in crowd sensing.
3. Quality of information
   Using Lokemon, people can concentrate on achieving the task of reporting information from that particular location. Also, since each Lokemon has an each character visual design, reported information and/or people's behavior might be controlled with the design.

2.3 Sociological theory behind Lokemon

Lokemon's potential for solving the issues can also be explained by introducing several sociological theories. First, dramaturgy theory[5] suggests that the design of Lokemon might enhance information quality. Dramaturgy, originally developed by Erving Goffman, argues that human interactions are always influenced by time, place, and audience. It suggests that a person's identity is not a stable and independent psychological entity, but rather gets remade as the person interacts with others. In other words, people always have to aware of whether they are playing an expected role, or change their behaviors to manage the impression they make on others. Since Lokemon forces users to act as the Lokemon rather than themselves, they can focus on playing a more stable role/character as the Lokemon, rather than varying their behavior to make a particular impression on others. Thus, Lokemon provides a stable front stage and guide of performance for the users. In addition, the concept of positive/negative face or face-threatening acts in politeness theory[6] also suggests that Lokemon provides safe opportunities to help others while avoiding excessive mutual interference. In the real world or when using a user name that identifies each user, it is difficult for users to balance positive face and negative face. By mediating their communications through a virtual monster that is characterized by a common identity for the PoI, users can meld into a common identity shared by other people. This could help to enhance users' motivation to participate in crowd sensing.

3 Programming Model

We propose a programming model for computing people (leveraging people as a part of sensing/actuating in program) through Lokemon. Instead of requesting users directly to undertake various tasks such as sensing or acting, our model places requests to users indirectly by doing it through Lokemon. Moreover, our model enables developers to access data both from IoT and people (Lokemon) via unified APIs. We adapted the Publish-Subscribe model to access

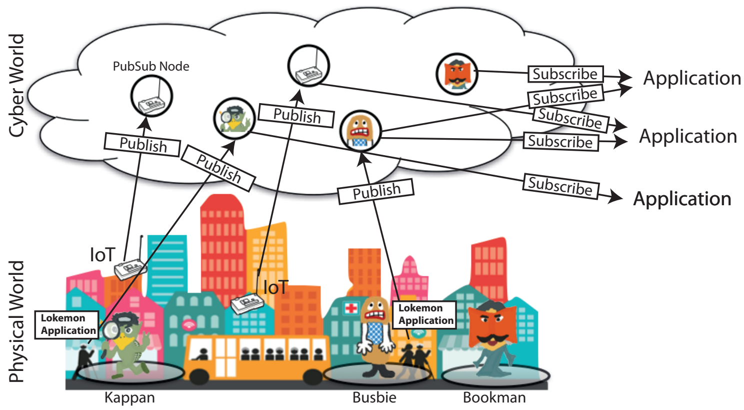

Fig. 2. IoT sensors are placed to phyiscal world. Lokemons are placed virtually to each locations. Applications can access them via PubSub nodes, which are associated to each IoT and Lokemon, by subscribing or publishing the nodes.

sensors/actuators including IoT and Lokemon. Each IoT/Lokemon is managed as a PubSub node, and applications can leverages data of the node by subscribing the node or publishing data to the node. This allows developers to make applications easily because both IoT and Lokemon can be treated in the same way as real-time data streams. Fig 2 represents how data from IoT and Lokemon are flowed in the same manner. In the figure, two IoT sensors are deployed in the physical world. They periodically publish sensor data to the PubSub node corresponding to the each IoT sensor. In addition, three Lokemons named Kappan, Busbie, and Bookman are deployed virtually at several locations, and people who are located closely to each Lokemon publish sensor data as Lokemon by using the Lokemon application. Third party applications can retrieve data from both IoT and Lokemon in a unified way by subscribing to PubSub nodes corresponding to each IoT and Lokemon. Thus, information from Lokemon can be regarded as open sensor data streams just like public IoT sensors. One of advantages of the programming model is to provide simplicity; developers do not have to specify exact users to interact with. Developers can make use of sensor data from people who are in PoI by accessing virtual sensors as Lokemon. For the PubSub-based platform, we extended the sensor-over-xmpp protocol [7] [8] to manage not only IoT sensors/actuators but also crowd sensing nodes with Lokemon. In addition, we also made use of our XMPP server implementation, SOXFire [9], which is designed for distributed and federated infrastructure for data sharing among various users/organizations in a way that is scalable, extensible, and easy to use and secure.

4 Experiment

4.1 Purpose of the experiment

To evaluate the effectiveness of a Lokemon model, we conducted a experiment that compared two different applications-a crowd sensing application with a Lokemon mode (called the Lokemon application) and another lacking Lokemon (called the Lokerepo application). We recruited 34 students aged 19-30. We offered them a reward of 3,800 yen at the end of experiment, and divided them into two groups (17 each) randomly. One group installed only Lokemon, and the other group installed only Lokerepo on their smartphones. The experiment took place between January 24th and February 28th. Because the experimental period coincided with the spring vacation, we recruited students who planned to visit the campus for more than seven days during the period. At the beginning of the experiment, we taught each group how to use Lokemon or Lokerepo as appropriate. We did not force the users to use Lokemon/Lokerepo. We required only that the users always have Bluetooth turned on, allowing notification from the application. The experiment allowed us to compare the difference between of the number of reports and communications among participants using Lokemon and those equipped with Lokerepo. Finally, we conducted a questionnaire survey to help us understand the participants' impression of the applications.

4.2 Prototype applications and experiment setting

We implemented two iOS applications - Lokemon and Lokerepo. In both applications, the users' basic task is defined as to reporting current information from each location. For each PoI, we prepared a virtual noticeboard at the locations where participants could report current information. Messages in noticeboard can be also accessed remotely so that remote users can ask questions to possible users who are/will be at the locations. In other words, prototype applications were designed to work as a location-oriented Q&A service. In Lokemon, participants can report sensing information by mimicking monsters, which are virtually placed in each PoI (though those asking remotely were supposed to use their username). In Lokerepo, on the other hand, participants have to use their registered username (real name or a pseudonym) every time they used the application.

We defined nine locations in our campus as PoI - Theta building, the bus stop, the Subway restaurant, building Iota, Kappa building , the Yukichi statue, the Gulliver pond, the co-op store and Omega building. Figure 3 shows the nine locations and the Lokemons designed by the authors and placed in each PoI. We also installed iBeacon nodes in each PoI to specify the users' location. We set iBeacon's signal strength as "far" mode, which can be detected within a distance of about 10 meters. When the users enter each PoI (i.e.,. the iBeacon signal area), a notification is sent to the user's smartphone to make them aware of the existence of the PoI. Users with the Lokemon application can then pretend to be the Lokemon associated to the PoI to report information. GPS can also useful for specifying the users' location, for implementing Lokemon, but in this experiment we used iBeacon to specify location more precisely. Figure 4 shows screenshots of implemented applications. We designed and implemented iOS applications of Lokemon and Lokerepo to provide very similar usage for the users. The only difference was that the Lokemon application expresses each PoI as its Lokemon, enabling the users to pretend to be a Lokemon. Other functions such as receiving notifications when users are within PoIs, when any reports/questions are posted, the interface design for map and posting messages take the same form in the two applications (see Fig 4).

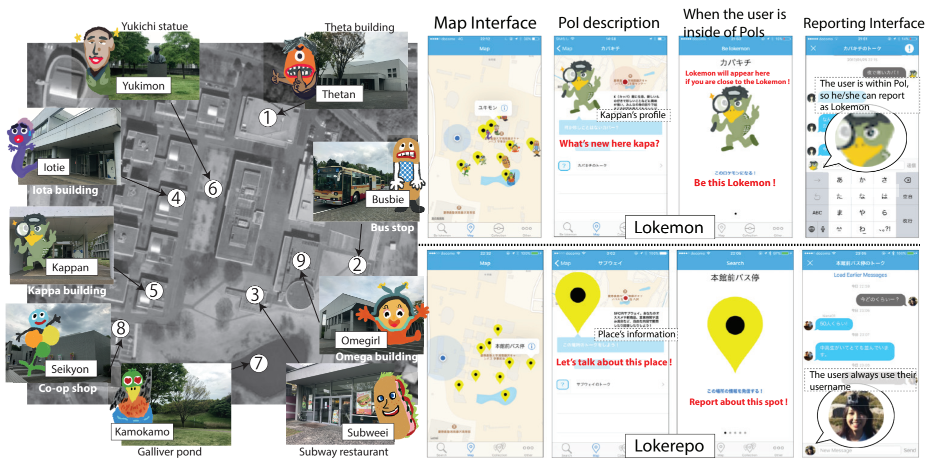

Fig. 3. Locations of the nine PoIs in the campus, and the identities associated with the Lokemon at each PoI (left). Screenshots of Lokemon and Lokerepo (right).

4.3 Experimental result

This section describes experiment result and discusses the particular effect of Lokemon. In both applications, participants asked/replied questions about current information near each PoIs such as the current length of waiting line at bus stop, or whether the shop was open or closed. All communication in both Lokemon and Lokerepo was done in Japanese. We translated the original messages into English as far as possible in the explanation below while retaining original nuances of messages.

Difference of collected information In all, we received 153 messages in Lokemon, and 114 messages in Lokerepo. Thus, Lokemon collected 134% number of messages compared to Lokerepo. In addition, in the case of Lokemon application, 72 out of 153 messages (47%) were posted as Lokemon (i.e., posted within PoI area). On the contrary, in the case of Lokerepo application, only

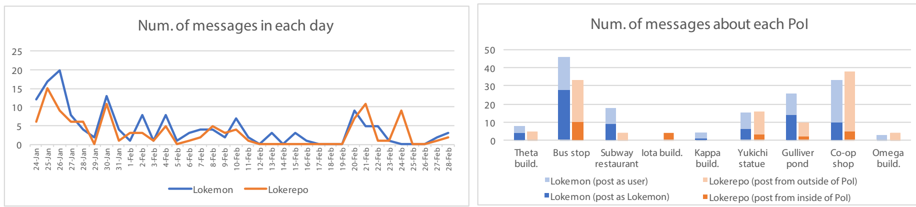

Fig. 4. Comparison of the number of messages in Lokemon and Lokerepo in each day (left) and in each PoI (right).

24 out of 114 messages (21%) were posted from inside of PoIs. Thus, Lokemon attracted more than twice messages from indside of PoIs compared to Lokerepo.

Right figure in Figure 4 shows the number of messages each day and relating to each PoI. The number of messages in Lokemon and Lokerepo show a similar pattern over the period. In terms of messages about each PoI, the total number of messages about the bus stop and the co-op shop are larger compared with other PoIs both in Lokemon and Lokerepo. The bus stop and co-op shop are often crowded, and we expected that the variation would be reflected in participants' interest in the PoIs. At both the bus stop and co-op shop, Lokemon gets more messages from the PoI (i.e.,. messages in the name of the Lokemon) compared with Lokerepo. By analyzing the content of the Lokerepo messages, we found that most of messages were questions from outside the PoI. Messages from inside of the PoI were relatively much fewer than those from than Lokemon users.

Next, in both Lokemon and Lokerepo, buildings Theta, Iota, Kappa, and Omega collected only a few messages. Those buildings are usually used for lectures; however, the experimental period was during spring vacation and no lectures took place in those buildings. That why those buildings did not get messages. In the Subway restaurant and Gulliver pond, Lokemon again collected more messages than Lokerepo. The differences were mainly due to the number of messages from inside the PoIs - about half the messages from the Subway restaurant and the Gulliver pond in Lokemon were posted using the Lokemon alias. Even when there were no questions from other users, participants voluntarily pretended to be a Lokemon to post messages about the PoI's current situation or their feeling about the mood as the Lokemon such as "No one here. I am very lonely. (posted by user A as Kamokamo)," or "Today's special lunch is Tuna sandwich! (posted by user B as Subweei)." In Lokerepo, we could not see this kind of messages.

Through these observations, we confirmed that Lokemon provided more than twice the opportunities to collect information from people who are in PoIs. This result implies that the Lokemon model could motivate people better than the traditional username model. Moreover, some users voluntary play a role as Lokemon to establish or assume the identity of the Lokemon's identity when they report current information about the PoIs.

Differences of communication between users We also observed that there are significant differences between the types of communication that take place between the Lokemon and Lokerepo users.

1. Many-to-one communication (Lokemon) vs. many- to-many communication (Lokerepo)
   In Lokemon, participants usually asked questions that address the Lokemon such as "Hey Subweei, what is your recommendation today? (posted by user C)" or "The wind seems to be strong today, are you OK Busbie? (posted by user B)." On the contrary, in Lokerepo, participants often addressed questions to "someone" who could help them such as "Does anyone know whether the Subway is opened now? (posted by user D)." In other words, the users in Lokerepo were often concerned about possible communication with unknown people. Lokemon provides a more simple communication option from many users to one Lokemon. Also, many people actually played a role as the Lokemon when they responded.
2. Casual communication (Lokemon) vs. Polite communication (Lokerepo)
   Another interesting observation in Lokemon was that people tended to communicate more casually compared with Lokerepo. When people address questions to a Lokemon, they say things like "Hey Busbie," "Are you cold?" or "Thanks!." Replies from Lokemon were also expressed in a casual or monster-like way such as "No one here!," "We are closed!," with attaching onomatopoeia at the end of messages to express the Lokemon's character, such as "(messages) kapa!," "(messages) BusBus!" or "(sentences) yo!." This onomatopoeia style was developed by the users themselves. On the contrary, in Lokerepo, people tended to ask/answer questions in a more polite way such as "Could someone tell me whether the shop is open or not?," "Thank you very much." or "Opening time in spring vacation is from 11:00 to 15:00. (in a polite way in Japanese)." We consider that Lokemon has the potential to enhance a friendly mood that contributes to the increase in the number of messages.

Questionnaire survey After finishing the experiment, we asked the participants to complete a questionnaire. Table 1 represents statements and averages of results obtained from the questionnaire. The respective ratings of agreement are: 1 = strongly disagree, 2 = partly disagree, 3 = neither agree nor disagree, 4 = partly agree, and 5 = strongly agree. In terms of pleasant, easiness, and motivation, Lokemon users gave better feedbacks than Lokerepo users. In addition, Lokemon users seemed to feel that the risk of loss of privacy is reduced by using Lokemon as a mediator of crowd sensing. These results show that we were right to predict that users of Lokemon would use this modality more. On the other hand, users of Lokemon seemed to consider that the reliability of messages is decreased slightly compared with Lokerepo. We take this to be a result of its anonymity feature. In future we need to evaluate Lokemon's reliability, by looking at the effect of feedback.

Table 1. Result of questionnaire.

Question	Lokemon	Lokerepo
It was pleasant to post message	3.6	3.2
Using Lokemon name (for Lokemon users) or Using username (for Lokerepo users) made it easy to post messages	3.8	2.5
The application enhanced my motivation to participate	3.3	2.5
The application decreased the reliability of messages	2.8	1.9
The application decreased the risk of loss of privacy	3.8	2.5

5 Related work

To motivate people to participate in crowdsensing, a lot of work have been conducted on incentive study. For example, the effect of monetary incentives has been investigated in [10, 11]. For non-monetary incentives, researchers mainly focus on psychological factors. For example, the study of gamification has been conducted in [12, 13]. The work of [14, 15] studied to use compliance-without-pressure technology to improve the receptiveness of participants. Our proposal is a new comprehensive approach of non-monetary incentives which uses techniques from sociology, psychology and anthropomorphism which have not been utilized in crowdsensing by now.

Lots of work have studied the use of avatars in virtual space communication and demonstrated that avatars does place an effect on people's behavior in both real and virtual worlds. For example, Yoon et al. [16] investigated whether certain types of avatars and avatar behaviors could promote pro- or anti-social actions of humans in daily behavior. Rosenberg et al. [17] illustrated the potential of using experiences in virtual reality technology to increase pro-social behavior in the physical world. To our best of knowledge, this work is the first attempt to promoting people's participation in crowdsensing via avatars. Moreover, in Lokemon, each monster can be mimicked by a group of people while in the aforementioned study each avatar can only be manipulated by one person.

Anthropomorphic design has also been widely applied to mascot characters, robotics, and entertainment games. Jetter et al. [18] explored how the physical design of urban sensors can change citizens' attitudes and perceptions toward being sensed. They found that anthropomorphic design resulted in greater engagement and trust while neutral or less visible designs created rejection and anxiety. Osawa et al. [19] proposed a direct anthropomorphic method that agentizes an artifact by attaching anthropomorphic parts to it. The study indicated that the examinees noticed the target artifact and memorized functions using direct anthropomorphism method more than doing so using an independent humanoid-agent. Compared with these study, our design applies an anthropomorphism of the property of location rather than physical objects, which has not been studied before.

6 Conclusion

We have presented a new crowd sensing model called Lokemon that mediates sensing subjects as location-aware virtual monsters. We addressed issues such as loss of privacy, providing motivation and controlling data quality in crowd sensing and showed that they are strongly related to aspects of the way of the sensing subject is structured such as whether the user identifies themselves using individual username or an alias. To address the issue, we introduced the concept of Lokemon that enables users to mimic location-aware monsters when they participate in crowd sensing. In addition, we also presented a programming model where a Lokemon can work as a virtual sensor node. Our programming model enables developers to create an application in a unified way that can handle data from both IoT sensors and people via Lokemon sensors. Through a small-scale four-week comparison experiment, we confirmed that the Lokemon concept was positively accepted by the users: Lokemon increased the number reporting from PoIs, and fostered casual communication among users while reducing their concerns about loss of privacy. In future, we will conduct a large-scale experiment to evaluate Lokemon's effectiveness. In addition, we will focus more on how the design of the Lokemon monster will affect the quality of information that people supply. Finally, we will make our Publish-Subscribe APIs public so that the Lokemon's crowd sensing data can be easily accessed. This should play an important role in realizing a programmable world that combines information from both IoT and people.

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