MinaQn: Web-based Participatory Sensing Platform for Citizen-centric Urban Development

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Abstract

This paper presents MinaQn[1], a web-based participatory sensing platform to enhance bidirectional communication between municipality and citizens for citizen-centric urban development. To make cities more comfortable to live, it is necessary for municipality to collect and reflect citizens' demands in their administrative works. MinaQn enables city officers to make various questionnaire to citizen easily, and citizen can answer the questionnaire with their location information through any devices by using WEB interface. The answers from citizen are collected as sensor data with unified format and protocol, so that the data can be shared and used for various applications. We designed and implemented MinaQn with web and XMPP technology, and carried out a two weeks experiment in corporation with 3 cities in Japan. Based on the experiment, we measured the effectiveness of MinaQn with qualitative and quantitative data. In addition, we also evaluated how citizens consider about providing their location information to the administrative works of the cities.

Author Keywords

Smart City; Participatory Sensing; City Applications; Citizen-centric Urban Development; Citizen Health and

[1]Mina means everybody in Japanese

Lifestyle Enhancement; Safety and Disaster Management; Experimentation; XMPP

ACM Classification Keywords

H.4.2 [Information Systems Applications]: Types of Systems—*Decision support,Logistics*; J.0 [Computer Applications]: General; H.5.2 [Information Interfaces And Presentation (e.g., HCI)]: User Interfaces—*User-centered design*

General Terms

Design,Experimentation,Human Factors

Introduction

The increasing concentration of the world population into urban areas puts the cities in the center of the preoccupations. On the other hand, developed countries including Japan are facing the problems of rapidly aging society. Therefore, in order to leverage limited resource effectively and make city more comfortable to many citizens, the importance of citizen-centric urban development will be more increasing in coming decades.

One of the key challenge towards citizen-centric urban development is to enhance communication among municipality and citizens. Since citizens have special and/or latest knowledge about their neighbourhoods, transferring those knowledge to municipality enables city administrative to work more effective. In addition, if municipality can ask citizens about the latest information of their area in disaster situation, it can help municipality's assessment of the situation and rescue planning.

In this paper, we present MinaQn, a WEB-based participatory sensing platform to enhance communication between municipality and citizens for citizen-centric urban development. Participatory sensing[11] is the concept of people contributing sensory information through the mobile devices which has multiple sensors. The aim of this paper is to extend the concept of participatory sensing for the context of citizen-centric urban development. The information which municipality wants to ask citizens dynamically changes day by day, especially in disaster situations. Therefore, simple and easy authoring tool for creating sensing tasks (i.e., making questionnaire) is necessary. This intuitiveness is also needed when citizens participate sensing campaign defined by municipality and other citizens. In addition, collected information should be opened and reusable for various applications as much as possible since the information has a great possibility to enhance city life.

MinaQn was designed to solve such problems, and motivating citizen to be in the loop of urban development by providing their knowledge to cities. With our implemented prototype of MinaQn, we carried out a two weeks field trial of participatory sensing involving municipality and citizens of 3 cities in Japan. Through the experiment, we collected more than 1,000 of sensory information from citizens. Of those collected data, we received more than 300 of answering data with GPS-based location information of citizens.

In summary, our contributions in this paper are as follows:

- Designing and implementing MinaQn, a open and scalable web-based participatory sensing platform for enhancing communication among municipality and citizens
- Verifying the effectiveness of MinaQn by demonstrating a two weeks experiment with both quantitative and qualitative analytics

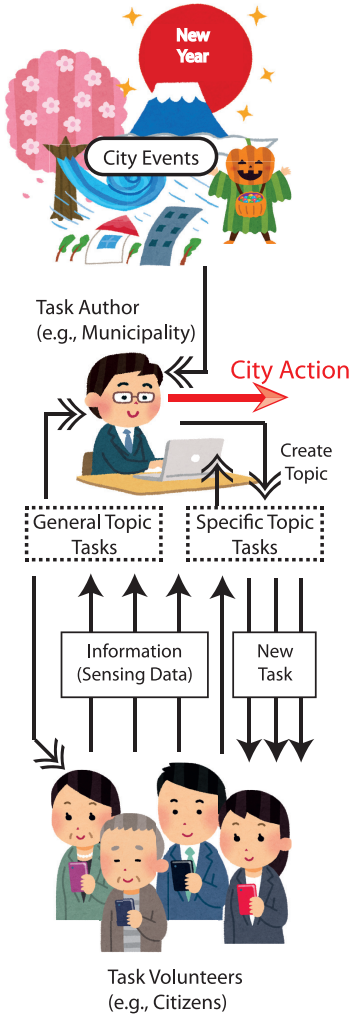

Figure 1: Participatory sensing model for citizen-centric urban development.

- Indicating guidelines to design future smart city development using participatory sensing

Design Considerations for Participatory Sensing towards Citizen-centric Urban Development

Urban development/planning is a technical and political process concerned with the use of land and design of the urban environment[2]. In addition to the definition of urban development, we include city administrative works such as city management and disaster control since these are very important and key functionality of cities. Citizen-centric urban development (CUD), also known as participatory planning, means that including citizen in the process of urban development. Many cities are currently focusing on CUD because CUD has great possibility to solve practical city problems with preventing conflict between various stakeholders in cities. One of the key indicators in CUD is the level of active communication among city stakeholders. Our aim is to leverage participatory sensing technology to enhance the communication. In urban development process, municipality wants to know problems and latest information about cities. If citizen can provide answers of such municipality's question easily through their mobile devices, it helps city to be more comfortable and reliable.

Figure 1 shows our proposal model of participatory sensing for CUD. In our model, there are two kinds of sensing tasks - general tasks and specific tasks. General tasks include sensing tasks which useful in everyday life, such as reporting damage of city infrastructure, traffic congestion, weather and so on. It also includes citizens' demands to municipality. Based on the sensing information from general tasks and also city events, sensing task authors (e.g., municipality) creates special sensing tasks such as reporting damage of typhoon, finding beautiful cherry blossom or how many number of kids get flu in your school etc. By repeating this dynamic task setting and answering, city officers can consider city actions to get their city better.

To realize this CUD cycle, participatory sensing platform has to fulfill following design requirements. Firstly, both task definition and task participation should be easily and intuitively achieved to involve many city officer and citizens in the CUD. In addition, it's better not to enforce any installation of the application in mobile devices of municipality and citizens. Secondly, the sensing data, which has no privacy risks, should be opened and usable for 3rd party application developers. Information from citizens are valuable to understand current status of cities, thus the data should be used by many developers of industry or NPOs. Thirdly, the platform should be secure and scalable because a lot number of citizens uses the platform. In addition, data format and data delivery protocol should be unified and extensible. These dependability and flexibility also helps 3rd party developer to create their original applications, and this in turn leads city eco-system among municipality and citizen.

There has been great efforts to improve and deploy participatory sensing technology [15][12][10][13][14]. Some of the works focused to sense special tasks such as garbage volume[12], city noise[15] or congestion pattern[10]. In contrast to these works, our focusing platform is necessary to define and distribute various sensing tasks to support CUD. In this context, there are some researches in tools or systems for task setting and facilitation of providing tasks to build an application for

[2] http://en.wikipedia.org/wiki/Urban_planning

participatory sensing, such as OpenDataToolkit[3], sensr[13] and medusa [14]. However, these works have several limitations to fulfill the requirements indicated - requiring application installation to the mobile devices or not opening the data widely. Especially, we focus to create easy, open, flexible and scalable participatory sensing platform based on standard technology such as XMPP for CUD.

On the contrary, there are some research focusing on incentives for participants. As research on monetary incentive, examining micro-payments for participatory sensing data collections[16] investigated the use of micro-payments as an incentive model. On the other hand there are researches on non-monetary incentive, for example distributing an application that provides beneficial information for users such as cophenhagen wheel[1]. Users can use the application as health care or navigation system while they are sensing environmental information for monitoring with their bicycles. Though we do not focus incentive mechanism for participatory sensing in this paper, we will include these knowledge in future development.

System Architecture

Figure2 shows system architecture of MinaQn with the whole flow of participatory sensing process. The flow can be devided into 5 main parts. At first, city officer creates a new participatory sensing task as questionnaire by using authoring web interface. After setting a questionnaire, he can also choose which questionnaire should be active. If he changed the questionnaire, the redirect destination URL would be changed dynamically. Therefore, once a static questionnaire URL is integrated with existing websites, it is not necessary to change a questionnaire URL every time even if city officer changes a providing questionnaire. A new sensing task will be created as a partcipatory sensing virtual sensor node. We designed an delivering data architecture for various applications capable of ensuring security and scalability. Citizens can browse active sensing tasks on the website and answer it anytime. After citizens answer the tasks, the sensing data will be delivered through virtual sensor nodes to subscribers of the nodes. In addition to real-time data delivery via PubSub functionality of MinaQn, collected data from citizens is also stored in a database as history data. Finally, the city officer can see all sensing results, and citizens can also see simple results without privacy data.

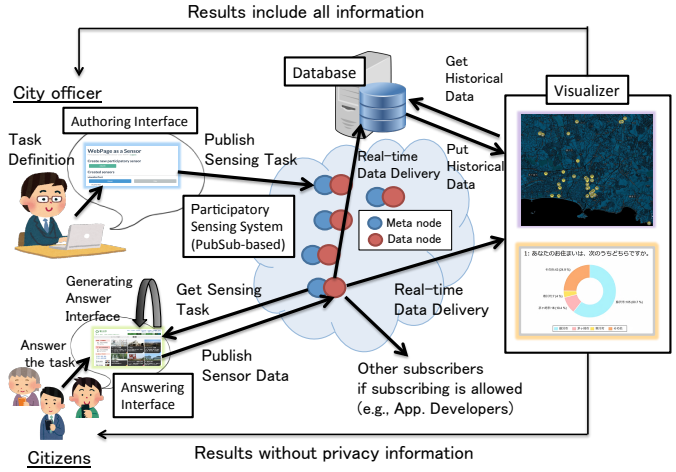

Figure 2: System architecture of MinaQn with the whole flow of participatory sensing process.

Implementation

MinaQn was implemented to fulfill the requirements of participatory sensing for CUD.

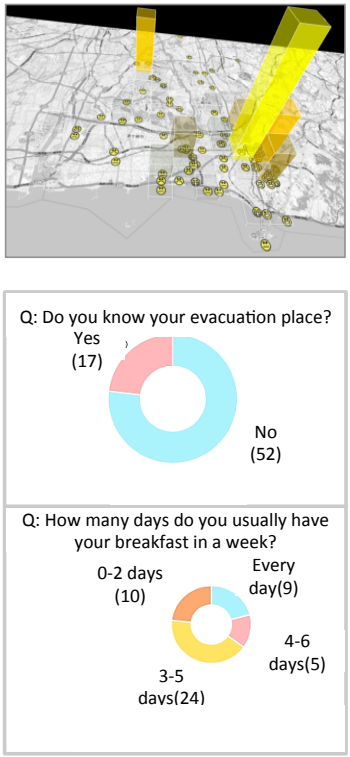

Figure 3: Different types of sensing data visualization: map-based (above) and chart-based (Bottom).

XMPP-based Sensor Network for Flexibility and Scalability
To treat citizens' opinions as sensor data, we used XMPP technology[9], which is the general term for protocol, client and server of open-source instant messenger based on XML. XMPP has a strong security, scalability and also flexiblity because XEP(XMPP Extension Protocol) is offered. In our architecture, as same as Sensor Andrew[17], we used publish-subscribe extension[7] of XEP. Using publish-subscribe extension, we can publish and subscribe sensor data from participatory sensing to a virtual event node which is defined as a participatory sensing task. When an application uses sensor data, it is not so important for the application where sensor data is gathered from. For any application, it would be enough if it could get only the necessary information. Therefore, we used publish-subscribe extension that any application can get sensor data by the unified API.

Unified sensor data format for participatory sensing by extending Sensor-Over-Xmpp
Our architecture is based on Sensor Andrew[17], which is developed in Carnegie Mellon University. Sensor Andrew is a middleware that can comprehensively handle sensor data of different sensor nodes and implemented on XMPP framework. Sensor Andrew also offers the Sensor-Over-XMPP(SOX) XEP[6] to cope with various physical sensors and actuators with unified format. When we use sensor data for applications, we need to know it's data format. In SOX, we treat a virtual event node as a pair, meta node and data node. Meta node has an information format of sensor data of participatory sensing. However, units about participatory sensing such as free form text, free form number, single choice(radio button) and moltiple choice(checkbox) were not defined in original SOX. Therefore, we extended Sensor-Over-XMPP[4] to deal with various participatory sensing information. By giving a description of definition about participatory sensing in meta node, we can get information about a user interface dynamically and generate suitable user interface for each questionnaire automatically when a user participates in sensing. On the other hand, data node has information about a citizen's position and an answer.

Intuitive Authoring and Answering WEB Interface with collecting location sensor data
To realize web based participatory sensing using XMPP, we used the Bidirectional-streams Over Synchronous HTTP (BOSH) technology[8]. BOSH is a mechanism to exchange XMPP protocol between a Web Browser and a BOSH server over HTTP. So, a Web XMPP client will run in the browser and use BOSH to communicate with an XMPP server. As shown in Figure4, on the top page of question management website city officers can create a new questionnaire and manage the existing questions. About management existing questions, you can see actual answer screen, check answer data, change which question to carry out, and delete a question. The question which is accepting answers is shown in red-colored characters. In answer part, we used an anonymous user to answer the question for ensuring privacy. The answer image is described in the next section.

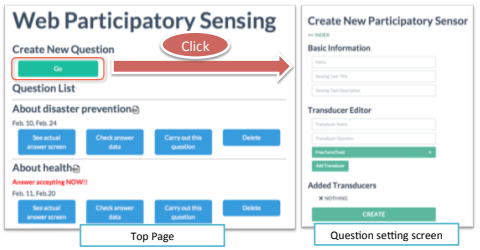

Figure 4: WEB interface for authoring participatory sensing tasks.

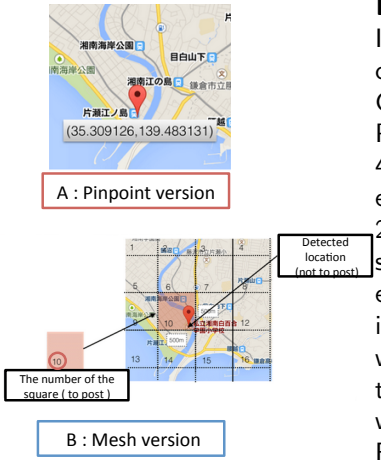

Figure 5: 2 type of ways how citizens privide location information.

We used the HTML Geolocation API[2] to get the geographical position of a user.Since this can compromise user privacy, the position is not available unless the user approves it. As shown in Figure3, we visualized the results by both 3D mapping in realtime and a pie chart with history data.

Experiments and Results

In order to validate our system and overall approach, we carried out our experimentation in 3 cities, Fujisawa City, Chigasaki City and Samukawa Town in Kanagawa Prefecture, which is next to Tokyo. The population is 40.9 million, 23.5 million and 4.7 million for each. The experiments were carried out from Feb. 10 2015 to Feb. 24 2015. WEB interface for participating sensing tasks is shown as Figure6. By clicking the question link on the exisiting website, the question page is shown as in the left image. We used 5 different websites including municipal website and the city information website by NPO. As for the question assumed disasters, we prepared 2 types of ways how citizens privide local information shown as Figure5. One is the pinpoint version, which provides the exact location where you are. Another one is the mesh version, which provides the number of the mesh devided into 500 meters square according to one's location. Either one of those were shown in a random order to the citizens.

Figure 6: WEB interface for participating sensing tasks.

Results in case of normal conditions

Table1 presents participatory sensing task results. The total number of answers were 939. Each question has one common question which asks a place to live and the rest was related to each question category. As a remarkable result, there was a differenece between quantitative data and qualitative data sensed from people. For example, the question about symptoms of hay fever was carried out 3 times and the distribution of answers differed clearly. As a result of questions, the probability of complaining of the symptom increased in the order of Feb. 13, 17, 23. However, according to the pollen count observation system by the Ministry of Environment[5] ,the total detected pollen count of each day increased in the order of Feb. 17, 13, 23. Therefore, we know that it is different between the place where citizens answered and the observation place, however, there is a possibility that participatory sensing will be useful for discovering a situation of a city that can not be predicted by quantitative data.

Results in case of abnormal conditions(with location information)

The experiments were carried out in Feb. 18 and Feb. 21. The total number of answers were 339 and the questions were about the place they live, their gender, age and physical condition. According to an access log, a ratio of users who did not shift from the explaination page to the actual question page is 44.33% in the pinpoint version and 41.43% in the mesh version. There is little difference in 2 types of providing location information, therefore when natual disasters occur, citizens would not hesitate providing their location information because of the privacy.As a result, nearly 90% of the total answered that when natural disasters occur, they would provide their location information or profile to a government willingly.

It is very meaningful for both governance and citizens to carry out participatory sensing with location information in the event of a natural disaster. What is more, over 80% of the total answered that they feel a need to share information with a local govenment and citizens.

Feedbacks from a municipality staff
We asked the munitipality staff who conducted questionnaires for 2 weeks to get feedbacks about our system.

Table 1: Participatory sensing task results.

Date	Question category	The number of questions	The number of answers
Feb. 10	Disaster prevention	3	173
Feb. 11	Health	3	82
Feb. 12	Eco-life	3	101
Feb. 13	Symptoms of hay fever	2	77
Feb. 14	Disaster prevention	3	72
Feb. 15	Sleep degree	2	81
Feb. 16	Locally-grown and locally-consumed	2	51
Feb. 17	Symptoms of hay fever	2	62
Feb. 18	Location and condition	5	166
Feb. 19	In Time of Disaster	2	72
Feb. 20	Health	3	41
Feb. 21	Location and condition	5	173
Feb. 22	Crime Prevention	3	42
Feb. 23	Symptoms of hay fever	2	44
Feb. 24	Disaster prevention	3	41

He thinks that the system was trial production so that the user interface should be updated, and he would use the system accordingly depend on contents of questionnaires. Also he answered that the system is very effective and needed for communication among municipality and citizens, because it can help municipality to get real time information including in time of disasters. Furthermore, he answered that it would be good to conduct questionnaires about not only municipal administration but also other things in a wide category.

Conclusion and Future Work

To make cities more comfortable to live, it is necessary for municipality to collect and reflect citizens' demands in their administrative works. MinaQn enables city officers to make various questionnaire to citizen easily, and citizen can answer the questionnaire with their location information through any devices by using WEB interface. The answers from citizen are collected as sensor data with unified format and protocol, so that the data can be shared and used for various applications. We implemented MinaQn with web and XMPP technology and carried out a two weeks experiment in corporation with 3 cities in Japan. As a result, we found that MinaQn enables to have a conversation with city officers and citizens. However, we still need to get more answers from citizens for practical use. For example, to make a clear aim for each questionnaire and show them to citizens would be one of the effective ways for getting more people to participate. Also, we will design a better interface and integrate our system with not only existing websites but also existing smartphone applications which can receive a push notification in appropriate timing. At the same time we will enhance system availability and implement the system which is easy to maintenance, to carry out large-scale and long-term experiments by increasing the

number of participants, question linked webpages, types of questions and conducting at other cities. We will also try to use not only participatory sensing but also other sensing data, so that we can realize multi-level sensing environment using our system. By sharing sensor data with other cities we believe that we can form a community exceeding a framework of an individual city.

Acknowledgements

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