On Feasibility of Crowdsourced Mobile Sensing for Smarter City Life

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Abstract. This paper introduces the ongoing project that aims to develop a mobile sensing framework to collect sensor data reflecting personal-scale, or microscopic, roadside phenomena by crowdsourcing and also using social big data, such as traffic, climate, and contents of social network services like Twitter. To collect them, smartphone applications are provided. One of the typical applications is a driving recorder that collects not only sensor data but also recorded videos from the driver's view. To extract specific roadside phenomena, collected data are integrated and analyzed at the service platform.

The proposed smartphone application can be replaced with appliances because of its advantages: (1) ordinary appliances work stand-alone, which means that local storage is limited; the application is connected to the cloud, (2) appliances are not cheep, at least users must pay for it; the application is free, (3) appliances only store driving records; the application can get feedback from the service. The authors expect that these advantages can be accepted by citizen as an incentive to use it. To reveal how effective such function is for users' motivation, an experiment and a survey are conducted with our prototyped service. As a result, most of the users accepted the function as attractive to use.

1 Introduction

Cyber-physical systems (CPS) seek to provide users with optimal control of the world they correspond with by modeling physical space in cyber space, coupled with the use of related databases. More than big data systems, social CPS is the operating system of urban society. It provides a user environment that supports the agency of people in decision-making. The need for social CPS in building sustainable, safe, and secure urban societies is growing. The prerequisite basic technologies are maturing rapidly. Remaining efforts include opening data silos maintained by the private sector and the government, and analyzing massive, complex data that cannot be completely described by a single monolithic model. Social CPS is filled with tantalizing challenges for research and development.

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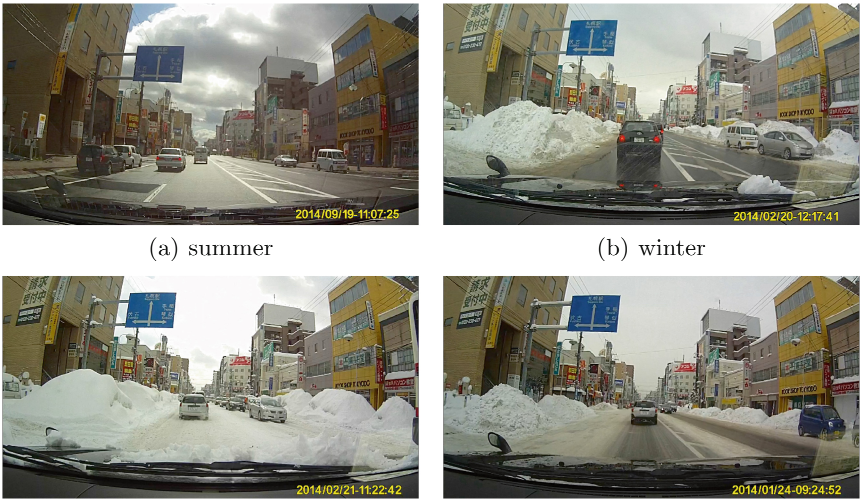


(a) summer (b) winter

(c) winter: heavy snowfall (d) winter: surface freezing

Fig. 1. Comparison of road conditions in summer (a) and winter (b,c,d). The road situations vary hour after hour, especially in winter.

This paper overviews the ongoing project of Social CPS, which aims to develop a mobile sensing framework to collect sensor data reflecting personal-scale, or microscopic, roadside phenomena by crowdsourcing and also using social big data, such as traffic, climate, and contents of social network services like Twitter.

2 Background

2.1 Civil Problems: A Situation in Sapporo

Sapporo has about 1.91 million citizens and 5.8 m average annual snowfall. The average amount of maximum snow depth reaches about one meter in February. It spends more than 15 billion Japanese yen every winter for the road management such as snow plowing and removing. The snowfall in winter cause significant changes to road condition shown in Fig. 1.

The traffic of winter road in Sapporo is strongly affected by amount of snowfall, snow depth, temperature, frozen road surface, traffic volume, snow plowing condition and other road conditions. For the analysis of dynamically changing traffic and road conditions in an urban-scale area, probe-car data may play the most important role. Inherently they are real time data, and have the potential to cover urban-scale areas. They can tell us not only about dynamically changing traffic and road conditions, but also about people's dynamically changing mobility demands and activities. Probe car data is expected to be used as fundamental to monitor and estimate the urban-scale dynamic phenomena of traffic and road conditions of all the road links, and also to monitor the snow plowing and removal operations.

2.2 Crowdsourcing for Civil Problems

The term "crowdsourcing" was described by Jeff Howe in 2006 [5] and defined that crowdsourcing is the act of taking a task traditionally performed by a designated agent and outsourcing it by making an open call to an undefined but large group of people [6]. This can take the form of peer-production, but is also often undertaken by sole individuals [4].

The concept of smart cities can be viewed as a recognition of the growing importance of digital technologies for a competitive position and a sustainable future [10]. Although the smart city-agenda, which grants ICTs with the task to achieve strategic urban development goals such as improving the life quality of its citizens and creating sustainable growth, has gained a lot of momentum in recent years.

Tools such as smartphones offer the opportunity to facilitate co-creation between citizens and authority. Such tools have the potential to organize and stimulate communication between citizens and authority, and allow citizens to participate in the public domain [1,11]. One example is FixMyStreet[1] that enables citizens to report broken streetlights and potholes [7]. It is important that these approaches will not succeed automatically and social standards like trust, openness, and consideration of mutual interests have to be guaranteed to make citizen engaging in the public domain challenging.

Waze[2] is another crowdsourcing service to collect data of traffic. Even though Waze provides users to traffic information collected from users and route navigation function, it seems not enough to motivate users to get involved in, because recommended routes are not as adequate as car navigation appliances, especially in Japan where such appliances are well-developed.

3 Crowdsourced Mobile Sensing and Its Applications

3.1 Overview

CPS is a promising new class of systems that deeply embed cyber capabilities in the physical world, either on humans, infrastructure or platforms, to transform interactions with the physical world [2,9]. CPS facilitates to use the information available from the physical environment. Advances in the cyber world such as communications, networking, sensing, computing, storage, and control, as well as in the physical world such as materials and hardware, are rapidly converging to realize this class of highly collaborative computational systems that are reliant on sensors and actuators to monitor and effect change. In this technology-rich scenario, real-world components interact with cyberspace via sensing, computing and communication elements.

Social CPS focuses human aspects in the parallel world because human is not only subject to exploit such systems but also object to be observed and

[1] https://www.fixmystreet.com/.
[2] https://www.waze.com/.

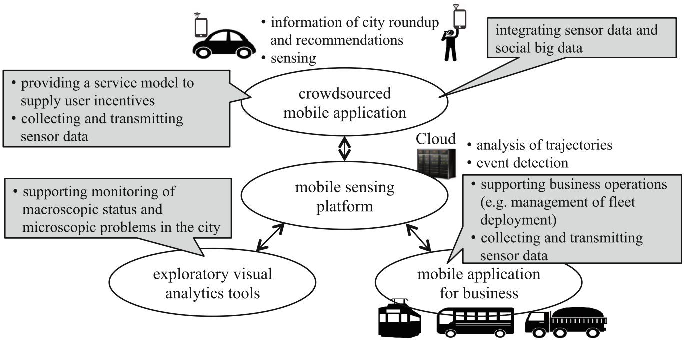


Fig. 2. Overview of the proposed mobile sensing system

be affected by the systems. Information flows from the physical to the cyber world, and vice-versa, adapting the converged world to human behavior and social dynamics. Indeed humans are at the center of this converged world since information about the context in which they operate is the key element to adapt the CPS applications and services.

Figure 2 overviews proposed systems for crowdsourced mobile sensing. At the center, cloud as a service platform is located. Above the platform, several applications are being developed.

3.2 Platform Service

The service platform facilitates applications not only to receive the transmission of data from applications but also to provide ordinary functions for location-based services, such as nearest and up-to-date places. The platform also plays a role to integrate collected data and social big data, such as traffic, climate information, and contents of social network services, and then analyze them to extract specific phenomena in the city, especially on the roadside.

Since the sensing data can be very large, data compression for reducing the storage and efficient processing are important for the crowedsourced sensing platform. However, the compression and analysis algorithms have been often developed independently, and the compressed data need to be expanded before analysis, which requires additional processing. To solve this problem, the authors are studying a platform where the sensing data is analyzed in compressed form. For this purpose, the authors study to apply the succinct data structure (e.g., [3]) to manage map information as well as location-related sensing data itself.

Various statistical analysis and data mining algorithms are applied to sensing data analysis. Among them, outlier detection is useful to detect events and anomalous situations. The authors developed an incident detection method from traffic flow data [8]. In this study, the authors first built a statistical model representing velocity distribution of cars for each road segment by exploiting large training data. Then, the authors compare velocity of a car passing through the segment with the model. If the velocity is a outlier with respect to the velocity distribution model, the authors judge the road segment is in a anomalous situation. Because of large amount of sensing data, the authors can use a complex model and achieve high detection rate [8].

Crowedsourced sensing data can be biased because users who provide the data are not always typical ones. When using a statistical model for the analysis as in our incident detection method, the authors need bias-correction.

3.3 Mobile Applications for End Users

For citizen as an end user, a mobile application is being developed upon the platform. Although the main target user is driver, the application can be used by pedestrians using public transport, such as subway and bus.

For drivers, driving recording function, or video event data recorder, is provided. Users mount such recording appliance to dash or even to windshield to record the behavior of the car during the driving, such as trajectory (a sequence of locations with time stamp), accelerations, speeds, and video. One of the biggest motivations to use such appliances is that they use records as reference back to accident scene. Users, therefore, should use the appliance whenever they drive. The authors expect that the proposed smartphone application can be replaced with appliances. The advantages are as follows:

1. Ordinary appliances work stand-alone, which means that local storage is limited; the application is connected to the cloud.
2. Appliances are not cheep, at least users must pay for it; the application is free.
3. Appliances only store driving records; the application can get feedback from the service.

The authors believe that these advantages can be acceped by citizen as an incentive to get involved in it.

The function of driving recorder has positive features to collect data reflecting roadside situations. One is that the data is collected whenever they drive. Power consumption is not critical because power can be supplied from the car. And also drivers' smartphones are not manipulated while they drive.

The detail of the driving recorder application is described in Sect. 4.

3.4 Applications for Civil Administration

In our prior study on CPS-IIP project, the authors have implemented smartphone-based mobile sensing applications for city buses and snowplowing cars respectively to investigate the influence of snowfall and snow removal operations on traffic. The experimental field is shown in Fig. 3(d). Mobile sensing system for buses is important to collect periodic and continuous road traffic information. The authors have implemented 20 bus-sensing system in cooperation with Hokkaido Chuo Bus, one of the bus companies operating city bus

(a) Hokkaido Chuo Bus

(b) Snow plowing vehicle

(c) Smartphone based mobile sensing terminal for operators

(d) The experimental field

Fig. 3. Chuo bus, snow plowing vehicle, and smartphone based mobile sensing terminal for operators.

service in Sapporo (Fig. 3(c)). The bus probe sensing data is useful for periodic and continuous monitoring of major lifeline routes. Meanwhile, the sensing system for snow plowing and removing vehicles is useful for monitoring snow removal operations. Both sensing system collects car speed, bearing, latitude and longitude by GPS. However, each of both system has individual information. The bus probe system has three-axis acceleration, route information and other operating information. On the other hand, the snowplowing car probe system has an operating type information (e.g. snow plowing or snow removing). Therefore, it is important to develop unified platform for mobile sensing, and it facilitates the deploying several applications for operation monitoring.

4 "Drive Around-the-Corner.": A Driving Recorder Application

The authors have developed and provides a driving recorder service called "Drive around-the-corner." since February 2015. The application got open to the public in February 2016[3]. Drive around-the-corner., Drive ATC for short, has the function of collecting behavior logs and posts of events and delivering information around current position.

[3] https://itunes.apple.com/app/drive-around-the-corner./id1053216595.

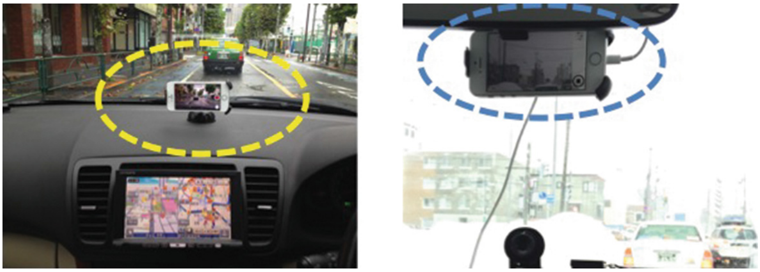
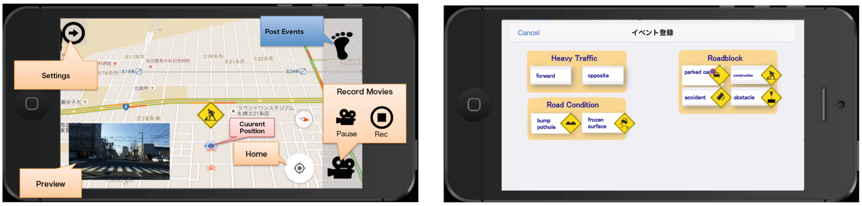


Fig. 4. Mounting smartphones on car.



(a) Main Screen (b) Post Events

Fig. 5. “Drive: around-the-corner.” application. Traffic information, events posted from users, events extracted from sensor data, and footprints are shown in map of main screen.

The service can be accessed via iOS application. Before driving, users mount their own smartphone and connect a cable for power supply if neccessary (Fig. 4), and then start recording in the application (Fig. 5). That is all to get ready to use.

While they drive and use the application, behavior logs and movies are recorded and uploaded to the service platform.

4.1 User Functions

Map with Event Information. When the Drive ATC application is invoked, it shows a map around the current position (Fig. 5(a)). Roadside events are retrieved on the service platform and get shown on the map. For example, the yellow icon is located at the center of Fig. 5(a). The icon denotes road construction and the information was posted by users of Drive ATC before.

And also footprint markers, which are placed on the locations where the user passed before, are snow as a triangle marker. The markers vary with the speed at the position. The shorter the triangle marker denotes the slower, the longer the faster.

Posting Event. To enable users to report a roadside event to others while they stop and wait for departure, the application provides the function to post an event information. After tapping the footprint marker on the top right corner,

Table 1. Collected data of Drive around-the-corner.

Type	Attributes
Location	latitude, longitude, and altitude with accuracy
Heading	true_north with accuracy
Move	speed, course
Acceleration	x, y, z
Rotation rate	x, y, z

users are requested to select an event that they realize (Fig. 5(b)). There are eight candidate events in three categories: heavy traffic, road condition, and roadblock. Selected event is posted with the current time and location to the service platform.

Settings. Menu button for settings is located at the top left corner (Fig. 5(a)). The menu list consists of "about the App", "Movie list", "Settings", "Event list", and "User account". Users can play recorded movies and also export them to the general image folder in the movie list.

4.2 Sensing Functions

User Data. The Drive ATC service collects the following user attributes:

- gender
- birth year
- zip code of home town
- email address
- nickname

The service collects these attributes at the first access.

Onboard Location and Motion Sensors. The Drive ATC application gets location and motion data from onboard sensors. While they drive and use the application, behavior logs and movies are recorded. Collected data are once pooled in the local datastore and then transmitted to the service platform. Collected data are shown in Table 1.

Movies. The Drive ATC application records two types of movies. One is to be uploaded and the other is to be saved locally. To reduce the traffic for uploading movies to the service platform, uploaded movie is intermittent and its frame rate is adapted according to the current speed of the car. For reference back to accident scene, locally saved movie in 30 fps can be used.

Table 2. Result of the survey

Question	# of answers
Motivation	
"Do you use the application instead of appliances if the application is cheaper than appliances?"	20
Attractive Functions	
Realtime information related to traffic	23
Route navigation to the destination	19
Automatic recording lifelogs that can be reviewed on the cloud	16
Sharing up-to-date posts from users	15
Requests	
Reducing size of locally saved movies	21
Reducing traffic for uploading data	17
Avoiding themal runaway	

4.3 Survey

To reveal how user functions, such as driving recording, affect users to get involved in the service, the authors conducted an experiment and collect answers to questions. 27 subjects out of over 50 participants in the experiment answered the questionnaire. The result of the question what applications they often use in Table 2.

For motivation, 20 out of 27 subjects agree that they select the application if it is cheaper than appliances. In addition, realtime traffic information collected from other users are regarded as attractive to use the application, which is not supported in appliances. The authors, therefore, believe that provided functions can perform as incentive to users to get involved in.

5 Conclusion

This paper overviewed the ongoing project that aims to develop a mobile sensing framework to collect sensor data reflecting personal-scale, or microscopic, road-side phenomena by crowdsourcing and also using social big data, such as traffic, climate, and contents of social network services like Twitter.

To make this framework effective, it is important that the system must deal with large scale data reflecting the daily life of citizens. The authors, therefore, also propose a service model to involve citizens.

The prototype mobile applications, Drive around-the-corner., has been delivered and started collecting crowdsourced data. Evaluating the methodology by using collected data is future issue.

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