Sensonomy: Envisioning folksonomic urban sensing

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ABSTRACT

Sensing urban environment with covering extensive area in a precise quality is important issue for sensor network approaches. This paper describes a system called "Parasitic Ambient Logger" which is attachable to mobile devices in order to sense ambient air environment. Unlike the conventional sensor network approaches, the system can build environmental sensing infrastructure in a cost effective way because it has less limitations of installation cost. Mobile sensor nodes should be able to know its location information for practical applications. Our method employs Wi-Fi based positioning technology which can get one's location even in daily urban environment. This grassroots style sensing environment helps to gain awareness of our surroundings. By aggregating the data, large dataset of ambient logging can be used to analyze long-term and city-wide urban environment.

Author Keywords

urban sensing, sensor network, folksonomy, mobile device

INTRODUCTION

Environmental sensing using ubiquitous sensor networks is going to be remarkable research fields in these days[1]. A common research topics in ubiquitous sensor networks has been the development of sensing infrastructure using low power static sensor nodes that are connected through wireless networks with flexible topologies. Although these approaches work well in a controlled environment, there are difficulties to install sensing infrastructure in a real-world to investigate city-wide activities[5]. For example, having to deploy large numbers of sensor nodes everywhere in our daily life is a most significant problem. Even if the enormous numbers of nodes could be prepared, getting property rights to install every nodes is almost impossible. Moreover, there are a lot of problems to overcome caused by its battery life, storage size, network access and initial location registration. Thus conventional style of sensor networks can not scale to the city.

One of the practical solutions for this problem, covering everywhere that we live with sensing infrastructure, is using a mobile platform[2][4]. If the sensors are embedded to the device that everyone already has (e.g. mobile phones, music players, portable digital assistants (PDA) and laptop computers), some kinds of limitation will dissolve. Sensors can get longer battery life and larger storage size derived from that of the mobile devices.

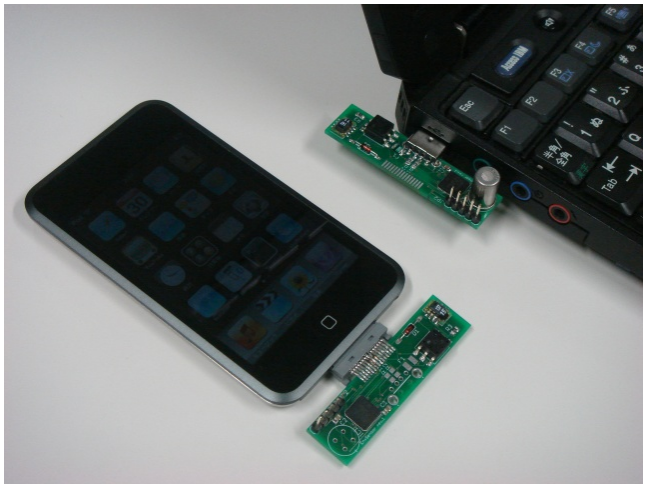

Figure 1. Appearance of "Parasitic Ambient Logger" System. (sensor modules attached to an iPod touch and a laptop computer)

We propose "Sensonomy" which is real world folksonomy based on various sensing technology and peer production. As folksonomy develop in Internet-mediated social indexing, "Sensonomy" is a bottom up style of mobile sensor networking by citizens in a real world. There are possibilities to realize various kinds of application under this concept (e.g. weather forecasting, pollution investigation, environmental sensing, etc.)

Most significant transition from static to mobile sensor nodes is location registration problem. Although the problem is even simpler for static sensors, mobile sensor nodes should know its location somehow by itself. In order to get location information of sensor node, one of the most applied technology is global positioning system (GPS). Although GPS device is widely used in static sensor network system in outdoor environment, it is not usable to detect one's location continuously in our daily life because performance of GPS declines significantly in indoor environment. Even in out-

UbiComp 2008, Sep 21-24, Seoul, South Korea.

door environment, the accuracy of GPS often getting worth in urban area due to buildings reflection. This problem also makes effective urban sensing systems difficult.

In our ambient logging system, we employ Wi-Fi based positioning technology[6][7] to enable each mobile sensor nodes to detect the location by oneself. By making use of densely installed Wi-Fi access points at urban areas, every Wi-Fi installed mobile devices get ability to detect its location in daily situation.

In this paper, we introduce our first proof-of-concept prototype, "Parasitic Ambient Logger", that is composed of common mobile devices that are easily available today and attachable tiny sensor device. Figure 1 shows working appearance of the system in two style, sensor module attached to music player (Apple iPod touch) and laptop computer. Using these kind of easily available devices and parasitically attaching sensors to get the help of computational and network resource, grassroots style sensor networks using mobile sensor nodes can be built in a realistic cost.

Following sections consist from the concept of proposed approach, system architectures, our proof-of-concept implementation of "Parasitic Ambient Logger" and its application examples. Our proof-of-concept implementation demonstrated that the system actually works effectively in a city environment.

PROPOSED APPROACH

In this section, we describe a concept of "Parasitic Ambient Logging" that can be alternate style of practical sensor networking model.

Mobile urban sensing

Environmental sensing in urban area is getting more important because of growing concern about investigating drastic change of climate or surveying air pollution over large scale.

Apart from conventional static sensor network infrastructure under controlled situation, sensing nodes in the form of mobile phone like devices are strongly needed to achieve this object[5][3]. Because deploying large numbers of sensor nodes everywhere in our daily life is impossible.

One of the practical solutions for this problem, covering everywhere that we live with sensing infrastructure, is using a mobile platform as seen in [2][4]. If the sensors are embedded to the device that everyone already has (e.g. mobile phones, music players, portable digital assistants (PDA) and laptop computers), mobile urban sensing can be realized

Most significant change between previous work and mobile urban sensing is how to tell the location information of sensor nodes itself. In case of that the node does not move, it is enough to tell location of the installed device manually at initial setting up process. On the other hand, it is essential for mobile sensor nodes to detect its current location somehow.

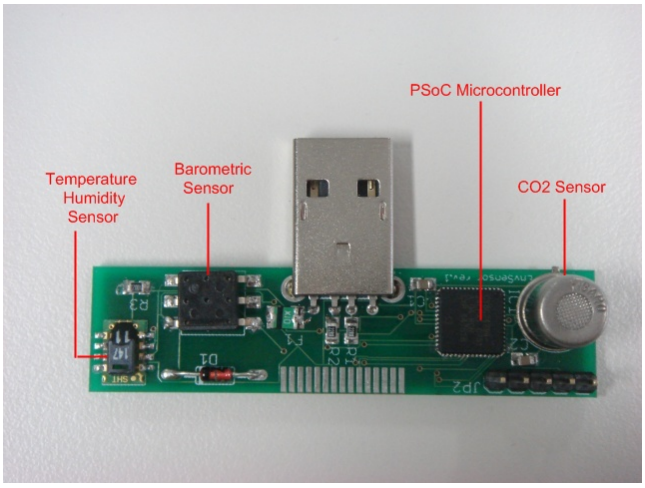

Figure 2. Top view of the sensor module (with USB connector).

Parasitic logger

There are some other kinds of problems to overcome that is specific to mobile urban sensing. Because of portability of sensor nodes, it is not easy for the primitive sensor nodes that have only lower functionalities to work properly in mobile context. For example requirement of battery life, storage size, network access are also becomes problems in this mobile urban sensing. Some kinds of computational abilities or network accessibilities is strongly needed.

It is ideal that embedding necessary sensors into mobile cell phones that already have longer battery life and storage size that can go through all day long and network accessibilities to share the sensor data, but it is hard to implement environmental sensors into today's cell phones because of its limited programmabilities.

Our approach employs keeping sensor module simple and resigning these capabilities to common Wi-Fi installed mobile devices which is available today (e.g. music players, PDAs and laptop computers). Parasitically attaching as simple as possible sensor module to, it can make the most of abilities from these mobile devices.

Ambient logging and location information

Urban sensing is a technology that records various low-level environmental information continuously and massively from our daily living space. It is important to sense location information where the data is captured and store time series of contextual information from environment. Such archived information can be used for analyzing working environment of a particular person, enhance the communication modality using contextual information around the users and surveying environmental information from geographical mappings of the data for city-wide scale. To provide such a statistical information in geographical views, most important information is "location" of where the data is captured.

Usually, GPS is used for location sensing as well known. However, GPS is not enough for location sensing, because

Figure 3. Wi-Fi access point locations estimation (Tokyo metropolitan area).

People's living space is mostly indoors and GPS does not work properly in indoor environments, and also GPS does not estimates building floor or room level location, which is important for mobile sensor nodes. Wi-Fi based positioning has a characteristic that it can estimate indoor location or building floor location. Thus we employ this technology.

SYSTEMS

In our "Parasitic Ambient Logger" system, each of sensor nodes is a set of common mobile devices with attached sensor module that is easily portable in one's daily life.

Our sensor module is composed of multiple single functional sensors and microcontroller (shown in Figure 2). Carbon dioxide, Barometer, Temperature and Humidity sensors are included in this module in order to measure ambient air condition and low level context information of the environment.

This sensor module has low-level sensors (carbon dioxide, barometer, temperature and humidity) and a microcontroller to sense ambient air condition. Derived sensor data from module is transferred to mobile devices via USB or serial port.

Wi-Fi based positioning

For Wi-Fi based positioning technology, we use "PlaceEngine" which is previously proposed by Rekimoto et al[7]. PlaceEngine maintains a Wi-Fi access point location database based on the estimation algorithm. The current database contains more than half million access point information that covers major cities in Japan (Figure 3). It also supports floor and room estimation based on Wi-Fi Signal fingerprint similarity. Using this technology, it becomes possible to record precise location log both indoors and outdoors.

Hardware details

We developed first implementation of our "Parasitic Ambient Logger" using some kind of low-level ambient air sensors and a microcontroller. To explore the idea of sensor modules this implementation keeps flexibilities in communication method between the mobile devices. An detail list of components is shown in table1. We use Cypress PSoC microcontroller to make use of its analog amplification and conversion capabilities for capturing the data from sensors.

Function	Components
Microcontroller	PSoC CY8C24794-24LFXI (Cypress)
Carbon dioxide	TGS4161 (Figaro)
Barometer	FPM-15PASR (Fujikura)
Temperature/Humidity	SHT15 (Sensirion)

Table 1. Component list of sensor module

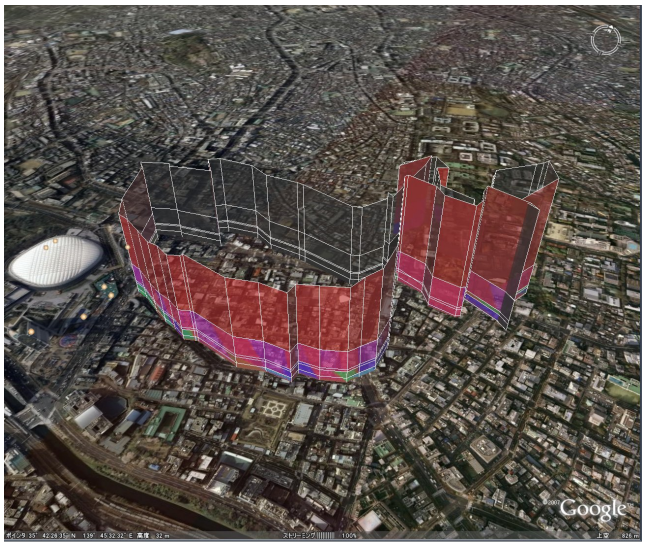

Figure 4. Visualization example of ambient logging. Sensor output data (CO2, barometer, temperature and humidity) is overlaid to its location.

APPLICATION

Given the continuous ambient logs with location information are available, a lot of applications can go through. Figure 4 shows the plot of the sensor output to a map. This kind of geographical representation is easily applied not only time-based plotting of the sensor output data.

DISCUSSION

For applications described above, most important thing is data and how to aggregate it, not a particular device. Hence heterogeneous sensor devices and its connection styles are possible. Figure 5 shows the possible variations of "Parasitic Ambient Logger" system configurations. There are many kinds of mobile devices in the world, so that one and only configuration of sensor module is not enough to achieve real-world sensor networks. For example, (a) shows simple and ideal one. At this moment, it is difficult to embed environmental sensors to mobile phones, because of size and energy consumption problems. (b) is more realistic one at now. sensor modules are connected to mobile phones via bluetooth. (c) and (d) are example configurations demonstrated in this paper. Thus various kinds of configurations are possible.

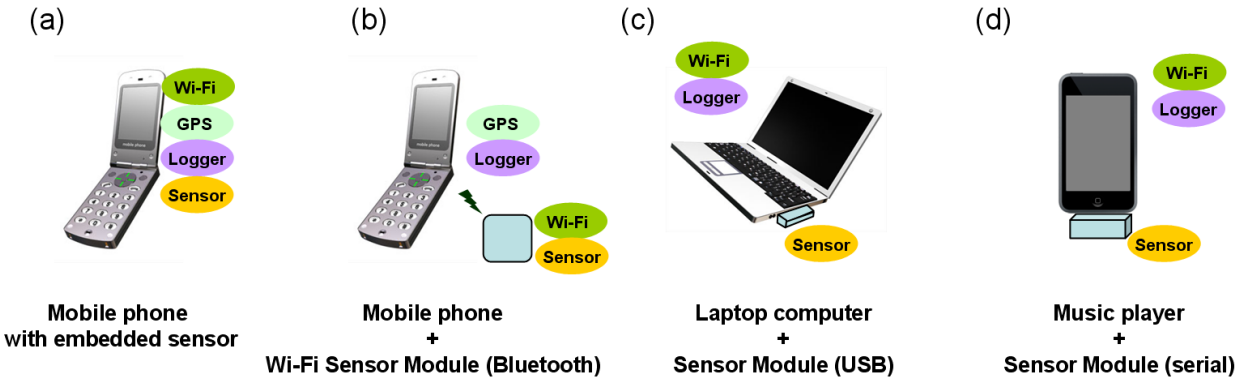

Figure 5. Variations of "Parasitic Ambient Logger" system configurations: (a) Mobile phone with embedded sensors, (b) Mobile phone and Wi-Fi ready sensor module (connected via Bluetooth), (c) Laptop computer and sensor module (connected via USB), (d) Music player and sensor module (connected via serial)

CONCLUSION

In this paper, we introduced the main concept of "Parasitic Ambient Logger" that employs mobile sensor nodes to sense large-scale urban environment, its practical implementation and its application examples in urban area. This can be alternative approach against conventional sensor network infrastructure with static sensor nodes. Major characteristics of this technologies is using single function sensor modules attached to commonly available mobile Wi-Fi devices. Simple time based matching of sensor data and location information from Wi-Fi positioning techniques make mobile ambient logger possible. Compared with GPS, Wi-Fi based positioning can detect one's location with high accuracy in most urban daily situations. Thus a mobile sensor node approach in urban environment fits to an application area of Wi-Fi positioning system. Our proof-of-concept prototypes are demonstrated that the mobile sensing platforms works effectively in urban environment.

BIOGRAPHY

Takashi Miyaki is an assistant professor in the Interfaculty Initiative in Information Studies at The University of Tokyo.

His research interests include human computer interaction, real-world sensing, life-log computing.

Jun Rekimoto is a professor in the Interfaculty Initiative in Information Studies at The University of Tokyo.

His research interests include human computer interaction, computer augmented environments, mobile/wearable computing, and ubiquitous computing. He has authored dozens of refereed publications in the area of human-computer interactions, including ACM, CHI, and UIST. In 2007, He was elected to ACM SIGCHI Academy.

He suggests "Sensonomy" which is real world folksonomy using various kind of sensors.

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