Sensing Web: To Globally Share Sensory Data Avoiding Privacy Invasion

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ABSTRACT

This paper gives an overview of the Sensing Web project, launched in 2007 in Japan. The project's aim is to open the data obtained by the sensors existing in our daily living environment for various purposes. Since the data obtained by observing the real world directly with sensors include real-world information different from the Web, a new worldwide social information infrastructure - Sensing Web - is realized. In this article, we discuss the research issues for arising in connection with the Sensing Web.

Keywords

Privacy-invasion-free, sensory data, information infrastructure, symbolization

1. Introduction

Recently, many kinds of sensors, including obstacle sensors, video cameras, thermometers, and so on, have been installed in various places in our daily living environments: stations, streets, malls, etc. Some of those sensors constitute sensor networks for exchanging their data in order to attain the purpose for which they are installed, more efficiently. In this article we refer to these networks as installed in our daily environments Ubiquitous Sensor Networks (USNs).

Each USN is installed by some institution including a local government, a transit company, a security company, and so on, for some specific purposes: traffic control, building management, video surveillance, etc. The sensor data obtained from the USN is used only for the purpose by the institution exclusively. However, such sensor data can actually be used for various purposes other than their original purpose, because the data include raw real-time information of the real world. If the sensor data were opened to the public so that anyone can use the data for their own purpose, similar to the Web, the data could serve as a new worldwide social information infrastructure that supplies the information different from that supplied by current Web. In this paper, we call this new social information infrastructure the Sensing Web. Whereas the Web supplies organized information collected and organized manually by humans, the Sensing Web supplies raw real-time information directly acquired from the real world. The Sensing Web Project is a three-year project launched in Japan in the Fall of 2007, aiming to develop information technologies necessary for making the data of USNs accessible by anyone..

2. Web versus Sensing Web

The Web is the only worldwide social information infrastructure currently open to the public. Almost all of us strongly rely on the Web as the single most important source of information for our daily life. Many businesses also rely on the Web as the preferred communication medium with their customers. However, all the information supplied by the Web is not raw information of the real world, but well-organized information composed manually or semi-automatically by humans. On the other hand, the *Sensing Web*, supplies raw real-time information obtained by observing the real world directly with sensors. In order to realize the *Sensing Web*, new information processing schemes, similar to those currently used in the Web, must be introduced into the raw, real-time, real-world information from sensors. In order to clarify these information processing schemes, we first describe those which are realized in the Web by considering how the Web has been developed before it became the only worldwide social information infrastructure. We then discuss what schemes are required for realizing the Sensing Web.

2.1 Development of the Web

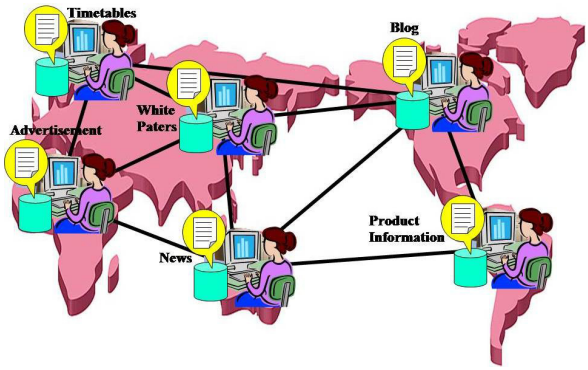
The development of the Web begins with the Internet, which is constituted as the result of connecting computer networks specific for military, scientific research, university LANs, etc. with one another by sharing the same communication protocol called *TCP/IP*. The Internet can be regarded as a scheme for worldwide data transmission, because it realizes data transmission between any computers in the world, regardless of their system configurations (see Figure 1(a)).

The Internet made possible the development of the *World Wide Web (WWW*) to share multimedia information transmitted over the Internet. Since the WWW makes any multimedia information in computers connected to the Internet accessible by anyone using

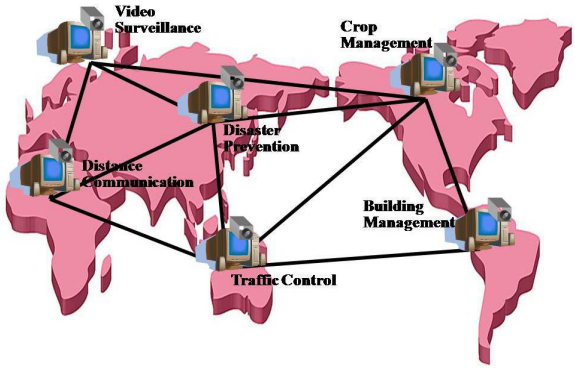
internet browsers (as long as the information is described in the form of HTML), the WWW can be regarded as a scheme for the world wide information sharing.

With the increase of information accessible through the WWW, *search engines* and *information portals* appeared so that their users can find the information that they want from that stored and accessible by the WWW. These search engines and information portals can be regarded worldwide information utilization schemes.

Since this triplet of (i) the schemes for worldwide data transmission, (ii) information sharing and (iii) information utilization are available, the Web spread all over the world to be the social information infrastructure.



(a) The Internet



(b) Ubiquitous Sensor Networks

Figure 1 Comparison beween the Internet and USNs as the data transmission scheme.

2.2 Comparison of the Sensing Web with the Web

The USNs, which have currently been constructed in various places in the real world, correspond to the computer networks constituting the Internet. By connecting the USNs all over the world with each other, a *worldwide sensor network* is realized, which makes possible data transmission between any sensors. This sensor network plays a central role in the worldwide information transmission scheme for the data obtained from various sensors installed in our daily environments. USNs are constituted of *sensor nodes.* A sensor node is a *(sensor, computer)* pair. An Internet-like structure where each node is actually a sensor node leads to the world wide sensing web, as shown in Figure 1(b).

However, just enabling worldwide sensory data transmission infrastructure, does not lead immediately to a social information infrastructure. Rather, as for the Web, schemes for information sharing and information utilization are required. After such schemes are developed, the existing USNs come to play a role of social information infrastructure for various kinds of applications ranging from communication, to shopping, or information services.

2.3 Privacy Information Management

The Sensing Web concept while similar to the Web, exhibits also important differences from it. The main difference is related to privacy issues: the information of the Sensing Web includes various kinds of private information related to the personal information of the people observed by the sensors. The privacy issue does not arise in the Web where most of the information is entered by humans such that privacy information can be removed or otherwise protected. Unlike the Web, all the information of Sensing Web is obtained directly from sensors, and therefore there is no chance to evaluate whether the sensor information violates individual privacy. Therefore a scheme for managing privacy information must be included in the sensor data, in addition to the schemes realized also in the Web (see Figure 2).

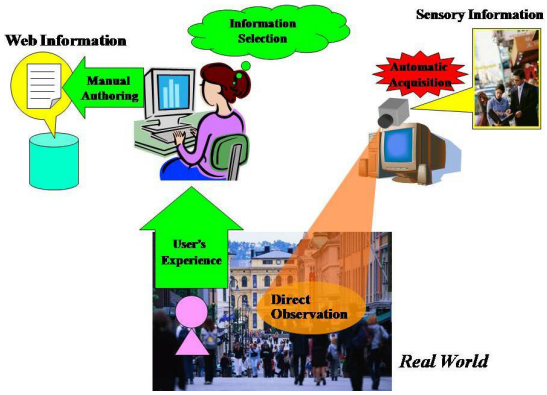


Figure 2 Difference between the Information in the Web and the Sensing Web.

3. Research Issues for the Sensing Web

In order for the USNs to evolve into the Sensing Web, we need to realize schemes for *information sharing, information utilization* as well as *privacy information management* for the information system characterized above. In our Sensing Web project, we will develop information technologies to realize such schemes including:

- privacy information management at sensor nodes,
- information sharing by matching information requests from the users with information services provided by sensors, and
- information integration for presenting the information obtained by various sensors in various places to the users comprehensively (see Figure 4).

In this section, we will describe the general approaches for these three research issues. In our Sensing Web project, we will develop information technologies to realize such schemes including three topics as shown in Figure 3.

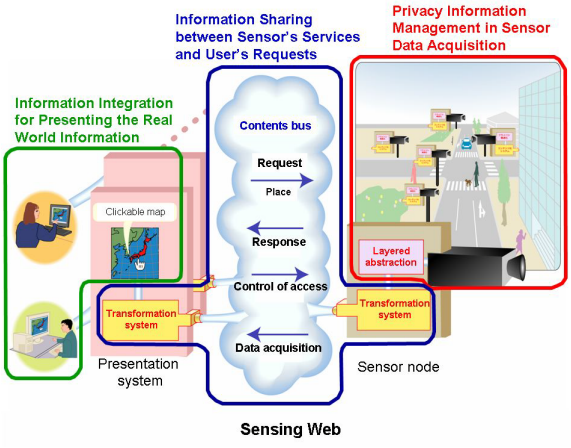


Figure 3 Research Issues for Sensing Web.

3.1 Privacy Information Management in Sensor Data Acquisition

The major difference of the Sensing Web from the Web is that the data obtained by the sensors include privacy information of the person observed by the sensors. This issue is heightened by the use of camera as sensors. One of the approaches to overcome this issue is the *stealth vision*[1], which motivated our project. In this project, in order to cope with the privacy information included in camera images, we propose that the real world information obtained as camera images is transformed into symbols and numeric data free from privacy information. Although sensor data includes various kinds of information, most of the real world information useful for our daily life does not related to privacy information, and can be described by a set of symbols from situation-specific vocabularies. For example, when interested in traffic conditions, the necessary information is not about the identity of the people walking or driving on the streets, but rather, about how many pedestrians/cars are on the street. Figure 4 shows examples of the data. Each sensory data is transformed into positions of people, obtained time and other properties, and described in XML format. This data does not contain appearances of the people so as to avoid the privacy invasion. In addition, the description is consistent among the kinds of sensors, so that the user of the data need not consider the difference of the sensors.

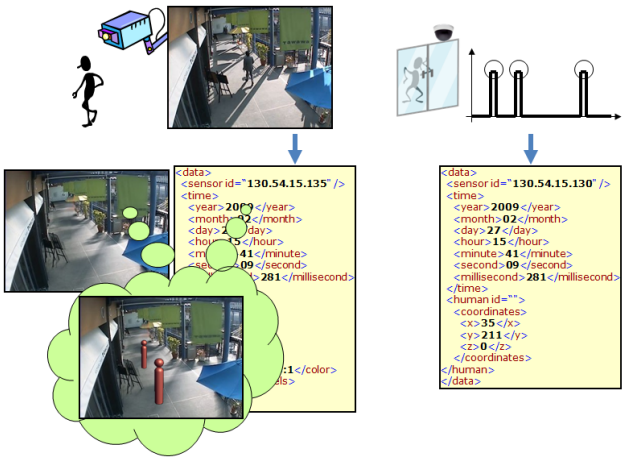


Figure 4 Sensory Data in the Sensing Web.

3.2 Sharing Sensory Data through Service/Request Matching

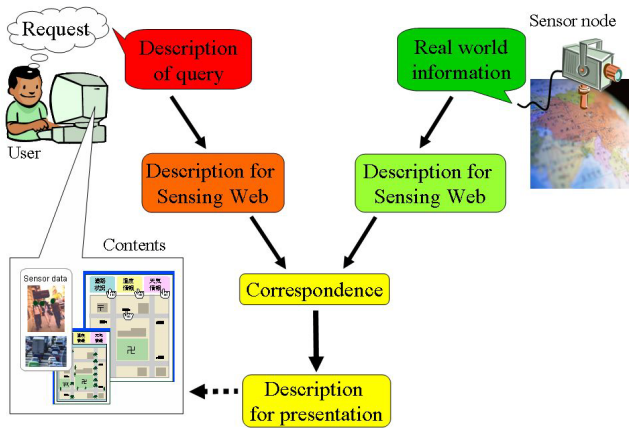


Figure 5 Smoothing Technology.

The Sensing Web uses the matching mechanism shown in Figure 5. One of research issues in this context is a *smoothing technique* to fill in the semantic gap between user request specifications (that should be reflected in the form of final presentation) and raw (but symbolized) sensor data. For example, when the trajectory of a person ("object") is needed for a service, the XML format can be easily transformed into ones focusing on each person while the data is originally described from the viewpoint of the frame of sensors, as shown in Figure 6.

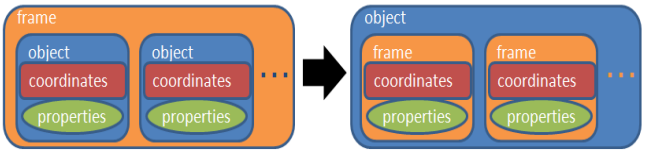


Figure 6 Transformation of the Data Description.

3.3 Information Integration for Presenting the Real World Information

Each sensor of the Sensing Web can only supply the information of the area observed by the sensor in the real world. In order to fulfill the requirement of the real world information from the users, sensor information from many sensors is needed. However, the data set resulted from many sensors is not appropriate for us to understand the situation of the real world. The sensor information from many sensors needs to be integrated into a single comprehensive description of the real world. Moreover, it is also desirable to relate the sensor information with the information obtained from other information resources including the Web. In this notion, we proposes several applications which integrate the data.

One of the applications is the *Digital Diorama*[2] technology which allows the users to view the real world from any virtual viewpoint (see Figure 7). Digital Diorama serves as *Google Earth*[3] composed by real videos. Google Earth supplies the users the views of the earth from the viewpoints and scales specified by the users. However, those views do not reflect dynamic change of the real world in real time, because they are generated by synthesizing the static views from satellite images.

When used in conjunction with the Sensing Web Digital Diorama supplies the views similar to Google Earth *synthesized from the real-time data* obtained by the sensors of the USNs.

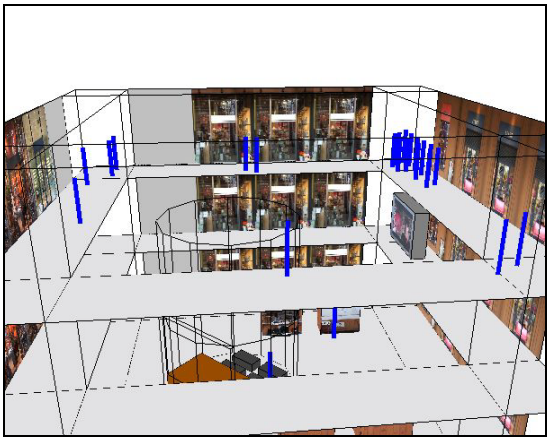


Figure 7 Digital Diorama.

4. Related Work

There have already been other proposals to utilize the data obtained from sensors installed in the real world. IBM constructs *Smart Surveillance System*[4], which uses many cameras to detect and track objects, for face cataloging, to index events and so on. In *Sensor Webs Project*[5] conducted by NASA JPL, many sensor nodes named *Pods*, equipped with various kind of sensors, are installed in real environments so that the sensor nodes gather the data of the environments by exchanging their data with each other. Similar research projects are also conducted by many universities such as MIT[6], Stanford[7]. However, most of these research projects use homogenous sensor nodes installed by the research organization itself for the express purpose of their research. By contrast, the Sensing Web project described here assumes the use of the sensors in the existing USNs, which have already been installed by various institutions for various purposes, independent of the Sensing Web. This means that sensors are heterogeneous and their positions cannot be designed and controlled by us.

Microsoft Research is also running *Sense Web Project*[8], which integrates still images uploaded by the users all over the world in the description of a map. This description is similar to the Digital Diorama of the Sensing Web. However, Digital Diorama does not limit the sensor data to still images taken by humans, but it can use any kind of sensor data obtained from the existing USNs. As a result, a richer and more dynamic real world description can be obtained while privacy of information issues is also addressed.

Other projects, including *Irisnet*[9] and *HiFi*[10], are also related with the Sensing Web from a viewpoint of processing complex queries over distributed sensors. Although this infrastructure may be partially effective for the Sensing Web, they do not consider the privacy protection.

5. Conclusions

We described an overview of the Sensing Web project, which aims to open the real world information obtained by various sensors of the existing USNs installed by various institutions for various purposes. The research issues for realizing the Sensing Web are management of privacy information included in the sensor data by pattern processing, transformation from the description of information query by users into that of information services given by sensors, and information presentation by integrating fragments of the real world information obtained by sensors. Since the information technologies required to solve these research issues include pattern processing, software engineering, media processing, researchers in the fields of these technologies join the project. Although the project is just at the beginning, we will develop these technologies for opening the sensor data of the USNs in the upcoming three years. Since it is quite important to extend this research to various countries for making the scale of the Sensing Web really worldwide, we are very much interested in the collaboration with the researchers in various countries.

6. Acknowledgements

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