Featured Articles

Use of IoT by Government Institutions

Hiroyasu Takagi
Tadashi Mima

OVERVIEW: Use of the IoT and other sensor technologies by the public sector is an emerging field, with scope for a variety of operational uses in the areas of information collection, policy implementation, and business resources management. Along with improving the productivity of tasks that were previously conducted manually, it also opens up the potential for new operational practices by enabling the movements and other information about large numbers of people and objects to be monitored in ways that are impractical to perform manually. Nevertheless, there are a number of technological, systemic, and organizational challenges and considerations to bear in mind when introducing sensor technology in practice. Hitachi looks forward to the public and private sectors working together on ways of overcoming these challenges so that, by making steady progress toward practical implementation, further advances can be made in the use of the IoT by government institutions.

INTRODUCTION

THE Internet of things (IoT) involves the exchange of information between all sorts of different devices. Driven by advances in sensors, networks, and other information technologies (IT), it has emerged as a full-fledged trend in recent years.

While private-sector businesses are already looking at a wide variety of applications for the IoT, some of which have already been implemented, it has yet to be wholeheartedly adopted by the public sector, particularly government institutions.

In recognition of this, Hitachi was contracted by The Institute of Administrative Information Systems in FY2014 to conduct a study of the potential for sensor technology in the public sector. This article reports on the results of this work.

SENSOR TECHNOLOGIES USED FOR IOT

Scope of Sensor Technologies

The study defined the scope of sensor technologies with reference to the fact that use of the IoT and big data can create value in a variety of different ways. That is, it encompassed not only sensor devices[1] that collect information on the external environment, but also sensor modules that combine sensors with communication functions, data networks (telecommunication networks), storage devices, and the cloud for storing data, and analysis techniques for extracting useful knowledge from the data (see Fig. 1).

Trends in Sensor Technology

Sensor technology in recent years has been characterized by improvements in the function of sensor devices and modules and advances in techniques for their mass production, including more advanced functions, the integration of multiple functions, and better reliability. An effort has also been made to reduce their power consumption and cost and to make them smaller and lighter for use in commercial and consumer applications.

In the case of networks, along with reducing the power consumption and increasing the speed of wireless communication systems, wireless sensor network technologies have also included advances in network control techniques such as ad-hoc networking whereby sensors relay communications for each other.

Improvements to storage technology have included higher capacity and faster data retrieval speeds, while in the cloud, interest has focused on the emergence of the database-as-a-service (DBaaS) model for the collection and analysis of big data and the use of non-relational databases suitable for handling unstructured data such as the numeric, text, image, and audio data that frequently features in big data.

In the case of analysis techniques, progress is being made in the development of stream analysis techniques

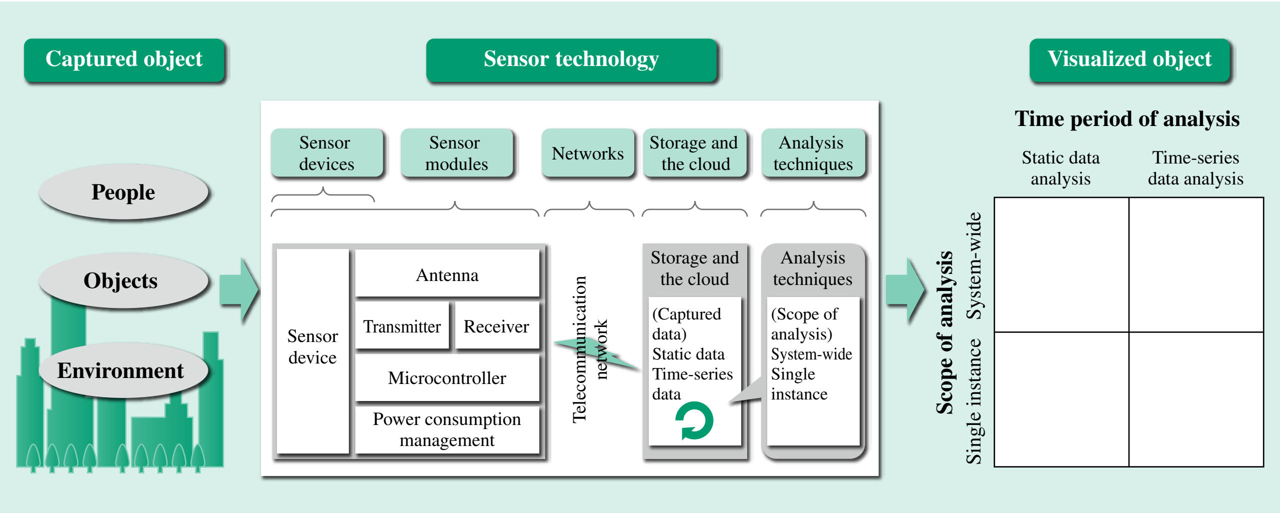

Fig. 1—Framework for Using Sensor Technology.
Hitachi developed a general-purpose framework that focuses on "captured objects" (the people, objects, or environment being monitored by the sensor) and "visualized objects," classified as the time period of analysis (the presentation of information from sensors using static or time-series data analysis) or the scope of analysis (whether considering a system-wide or a single instance).

such as complex event processing (CEP); stock analysis techniques that use technologies such as artificial intelligence (AI); and analysis platform technologies such as parallel distributed processing systems.

CASE STUDIES OF EARLY ADOPTION OF IOT

Collection of Early Adoption Case Studies and Consideration of Frameworks

To put these advances in sensor technology in context and understand how the technology is being put to practical use, Hitachi utilized websites and other published information to conduct a survey of examples of its early adoption by private-sector companies or local government agencies and other government institutions in Japan and elsewhere. The survey collected a total of 59 such case studies.

Hitachi also drew on the results of the survey to devise a general-purpose framework for the broad-based study of the potential for using sensor technology in the public sector, and used this in its appraisal of the case studies.

In devising the framework, Hitachi looked at the processes associated with the use of sensor technology and defined the terms "captured objects" for the inputs to sensor technology and "visualized objects" for the outputs, investigating these respective categories (see Fig. 1).

"Captured objects" are classified as either people (when monitoring the movements or other information about human beings), objects (when monitoring the movements or other information about animals or man-made objects), or the environment (when monitoring the weather, atmospheric conditions, forests, or other aspects of the external environment that are not covered by the above two categories). In contrast "visualized objects" are treated as classifiable in terms of the time period of analysis and scope of analysis respectively. The time period of analysis can be classified as either "static data analysis" when the analysis is performed on data taken from the captured object at a particular time, or "time-series data analysis" when the analysis is performed on data collected over time. Similarly, the scope of analysis can be classified as either "system-wide," indicating a fixed range or group in its entirety that is clearly defined by capturing data on a number of different people or objects, or a "single instance," indicating a particular person or object identified by capturing data about them.

Appraisal of Case Studies

Each of the collected case studies was assigned a position in a matrix based on their "captured object" and "visualized object" classifications, and an appraisal of these was conducted (see Table 1).

Looking at the distribution of the categorized case studies shows that examples involving the capture of data about people were the most common (37 examples), among which many examples involved the analysis of single-instance movements (time-series data analysis) or status (static data analysis) (28 examples). This was attributed to interest in things like

TABLE 1. Classifications for Sensor Technology Case Studies

The case studies of sensor technology use were classified in a matrix by "captured object" and "visualized object." The table lists a typical example from each category and the number of case studies for each.

	Static data analysis		Time-series data analysis	
	System-wide	Single instance	System-wide	Single instance
People	Use of image analysis to determine visitor attributes, etc. (2)	Transmission of video, audio, and location information for people or chairs to support telework, etc. (11)	Use of smartphone app and GPS to collect and analyze data on activities of foreign tourists, etc. (7)	Support for health by using wearable wristband sensors to monitor daily activity of staff, etc. (17)
Objects	Use of airborne drones with GPS, cameras, and other equipment to assess disaster sites, etc. (4)	Use of sensors to assess how full rubbish containers are, etc. (6)	Countermeasures for danger spots on roads utilizing data on locations where there is a high frequency of vehicles braking suddenly (1)	Use for taxation of driving distance and other data collected from vehicle-mounted systems with GPS, etc. (5)
Environment	Efficient monitoring of environmental pollution using chemical sensors on buses, etc. (4)	None	Providing and sharing information on weather situations by service users (2)	None

GPS: global positioning system

individual behavior analysis as being a trend in recent years. The results also showed a comparatively large number of examples involving the use of the portable sensors in smartphones to collect data on the system-wide movement of people ("people flow"). Specific examples included an initiative aimed at encouraging tourism by using smartphone apps and the global positioning system (GPS) to collect and analyze data on the activities of foreign tourists.

A total of 16 case studies involved the collection of data about objects. Specific examples included an initiative aimed at facilitating safety measures on prefectural roads by collecting location and other information from the car navigation systems of vehicles and analyzing it to identify sites where sudden braking occurs frequently.

Cases involving the collection of environmental data were few in number (6), with a feature being initiatives aimed at providing a more accurate "system-wide" view of the ever-changing environment. An initiative that has reached the implementation stage in one European city involves the detailed realtime monitoring of atmospheric pollution across a large urban area by attaching sensor modules fitted with GPS as well as chemical and other sensors to the roofs of buses to perform continuous air detection and measurement while in service, with data being collected via a wireless network.

POTENTIAL FOR USE OF IOT IN THE PUBLIC SECTOR

The operations of government institutions cover a wide range of activities. Considering the government management cycle[2], these areas of activity can be defined as information collection, policy making and budgeting, policy implementation, policy evaluation, policy improvement and institutional reform, disclosure of information, and business resources management. Hitachi has investigated the potential for use of sensor technology in each of these areas (see Fig. 2).

Specifically, Hitachi first looked at the characteristics of each area, the operations of entities such as central government agencies[3] and independent administrative corporations[4], and the role of sensor technology to investigate which areas have potential for using the IoT, narrowing down its focus to information collection, policy implementation, and business resources management (since policy improvement and institutional reform relates to the work done in policy implementation, it was included in that area). Next, an investigation into the potential for using sensor technology in these three areas based on the framework described above came up with a number of potential uses in each area.

Information collection includes activities such as statistical surveys and surveys of facility use, and Hitachi found that there is potential for using visible-light sensors (such as cameras), smartphones, vehicle-mounted sensors, and so on to collect movement and other status data on people, objects, and entire environments for tasks like these that to date have been undertaken manually by staff or others. Possible examples include the use of facial expression analysis to measure user satisfaction among people making inquiries at government offices, or using an analysis that can identify sites where there is a high frequency of vehicles braking suddenly to undertake safety improvements on roads managed by national or local government agencies.

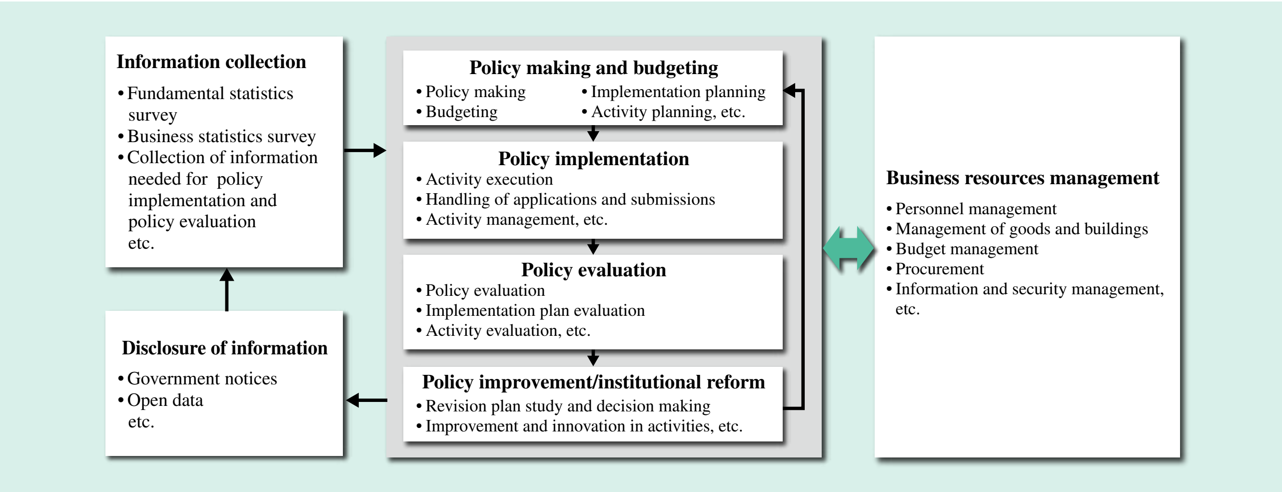

Fig. 2—Areas for Investigating Potential for Using Sensor Technology.
The areas of government activity were defined as being: information collection, policy making and budgeting, policy implementation, policy evaluation, policy improvement and institutional reform, disclosure of information, and business resources management.

Policy implementation includes activities such as over-the-counter services, border control procedures, taxation, and public works. These are areas in which progress has already been made on the use of sensor technology, but also with numerous possibilities for new uses. Possible uses for sensor technology include new methods of taxation based on parameters such as vehicle usage determined using automotive sensors, the use of GPS to obtain a situation overview during disaster and other emergency management, or the use of microwave sensors to identify people behaving suspiciously when passing through customs, for example.

Business resources management includes activities such as personnel management, management of goods and buildings, and budget management. Potential uses for sensor technology in this area include health monitoring for staff engaged in special duties that impose a high level of physical or mental stress, monitoring of staff movements or communications, and assessing the degree of aging of government buildings, for example.

In relation to the possibilities in these areas, the study also specifies some of these in more detail in preparation for their practical implementation, considering them in terms of how the work is currently done, the "captured objects," the sensor technologies to use, the "visualized objects," potential benefits, challenges, and issues to consider (see Table 2).

CHALLENGES AND ISSUES TO CONSIDER

There are a number of challenges and issues to consider in relation to advancing the use of the IoT by government institutions. In regard to technology, work is needed on things like the reliability and maintainability of sensor technology, data standardization, sensor network security, and measures for encouraging the switch to Internet Protocol version 6 (IPv6). Sensor technology reliability, in particular, is vital for avoiding false conclusions if the accuracy of collected data fails to satisfy requirements determined by factors such as the nature of the work for which it is intended. In relation to systemic matters, work is needed on things like privacy considerations, the provision and review of legal frameworks for government activities, and the review of frequencies used by networks and related matters. In the case of privacy considerations, it is important to clearly identify the data being collected and the reason for its collection, and to provide advance notification to the people being monitored (the "captured objects"). In cases such as using cameras to monitor visitors to public facilities and to classify them by attributes, for example, things that need to be considered include the use of signage or other methods to warn people that this is taking place, or the provision of alternative entrances that are not monitored by camera. Examples of organizational considerations include providing infrastructure designed to allow sharing between a wide range of entities that utilize sensors (including national or local government agencies), promoting the use of private-sector data, and training staff at government institutions so that they will be able to undertake data analysis. As noted above, given that sensor technology is likely to be used for a wide range

TABLE 2. Specific Examples of How Sensor Technology Can be Used

For typical examples of how sensor technology can be used in the information collection, policy implementation, and business resources management areas of government activity, Hitachi has devised more specific outlines of what form this use might take in practice.

Area	Activity	Basis of suggested use	Description
Information collection	Use facial expression analysis to survey user satisfaction among people visiting service counters at government offices	Current situation	As a means of determining how satisfied people who visit service counters at government offices are with the service they receive, Ministry of Health, Labour and Welfare or prefectural labor bureau staff, for example, stop people who have made employment inquiries at Public Employment Security Offices near the exit and interview them about their overall level of satisfaction with the service or their suggestions for improvement.
Information collection	Use facial expression analysis to survey user satisfaction among people visiting service counters at government offices	"Captured object"	Capture the facial images of people who have visited service counters or other points of contact with the agency. There is also the potential to track changes in facial expression by collecting data from both the beginning and end of the consultation, rather than capturing it only once.
Information collection	Use facial expression analysis to survey user satisfaction among people visiting service counters at government offices	Sensor technologies used	Use visible-light sensors or other types of camera to collect image data from service counter users and analysis techniques for detecting faces and interpreting facial expressions. Recognition of faces and parts of the body involves generating characteristics and rules from large quantities of image data and examples of correct recognition, and using machine learning algorithms to recognize faces and parts of the body using this data. The technique used to interpret facial expressions involves producing a shape model of faces from large numbers of image samples and then determining whether the shape resembles the model.
Information collection	Use facial expression analysis to survey user satisfaction among people visiting service counters at government offices	"Visualized object"	Use time-series data to analyze changes in the facial expressions of a person visiting a service counter at a government office, and present information on their level of satisfaction based on the expression interpretation (happy, surprised, fearful, antagonistic, angry, sad, expressionless, etc.) and circumstances.
Information collection	Use facial expression analysis to survey user satisfaction among people visiting service counters at government offices	Expected benefits	Whereas past methods have only surveyed a sample of users, this method can survey everyone. It also is less imposing on the staff who conduct the questioning and the service counter users who respond. There is also scope for presenting the obtained information on user satisfaction in ways that relate to different criteria, such as showing a low level of satisfaction among young males.
Information collection	Use facial expression analysis to survey user satisfaction among people visiting service counters at government offices	Challenges and issues to consider	The accuracy of sensor technology is not such that achieving 100% accuracy in the detection of faces and face parts or interpretation of facial expressions is realistic. Furthermore, in the case of an exit survey at Public Employment Security Offices, the checking of desirable improvements other than satisfaction and the use of sensors to replace all current activities is also not practical. Meanwhile, privacy considerations are one of the issues to bear in mind in relation to systems (organizational practices). It is likely that many service counter users will be resistant to the idea of recording and analyzing their facial expressions. Accordingly, potential measures include using signage or other means to clearly indicate to service counter users that their images are being recorded and analyzed for satisfaction measurement, and offering counters that do not use cameras.
Policy implementation	Levying of vehicle tax based on actual mileage	Current situation	Income from taxes such as fuel taxes levied at the point of sale will likely fall as vehicles with low fuel consumption become more common. Given factors such as the rapid aging of roads and other infrastructure in the future, it is likely that a review will be needed of how to use taxation for user-funding of road maintenance.
Policy implementation	Levying of vehicle tax based on actual mileage	"Captured object"	Record vehicle location information and distance travelled to determine actual mileage
Policy implementation	Levying of vehicle tax based on actual mileage	Sensor technologies used	Use an onboard information system (such as a car navigation system with GPS) and the vehicle's odometer. The collected data is sent from the onboard information system to roadside base stations. It is anticipated that this will involve a communication method that is difficult to intercept like that used for toll payments on Japan's ETC system.
Policy implementation	Levying of vehicle tax based on actual mileage	"Visualized object"	Data (including driving location and time information held by the onboard information system and distance travelled data) tagged with a unique vehicle identifier will be collected and analyzed by a government institution (or by a private operator contracted by the government) to make driving records for individual vehicles available.
Policy implementation	Levying of vehicle tax based on actual mileage	Expected benefits	This should provide a mechanism whereby users fund part of the cost of road and other maintenance based on how much they use the roads, to ensure that those who benefit pay their fair share.
Policy implementation	Levying of vehicle tax based on actual mileage	Challenges and issues to consider	Because providing driving data to the government will lead the drivers who are taxed to feel that their vehicle use is being monitored by the government, possible measures include ensuring that the data cannot be used for any other purpose or offering alternative means of taxation. In the case when existing onboard information systems are not designed to prevent tampering with driving data, measures will also be needed to prevent falsification. Furthermore, consideration of the mechanism used to collect the tax payments needs to account for matters such as the tax system. In regard to user-pays, there is also scope for using sensors to measure vehicle weight as well as other driving parameters, and to use these as a basis for taxation also.
Business resources management	Health management for staff with special duties	Current situation	According to the National Personnel Authority, an increasing number of people are requiring long-term medical leave due to mental or behavioral disorders, with workplace stress seen as one cause. Along with other support measures for maintaining and promoting the mental health of staff, the military, firefighters, police, and others who respond to major disasters are said to experience as much stress in three months as ordinary people experience in a lifetime, and therefore there is a particular need for health management support for staff who have special duties that expose them to danger or excessive stress.
Business resources management	Health management for staff with special duties	"Captured object"	Measure the action current (biological signal) for the electromotive forces of the heart associated with the action of the heart to record data such as electrocardiographic waveforms and heart rates for staff engaged in duties that expose them to danger or high levels of stress, such as the military or air traffic controllers
Business resources management	Health management for staff with special duties	Sensor technologies used	Use a shirt (wearable electrode inner) made from fabric coated in electroconductive polymer as an electrode to measure biological signals. The measured waveform data is transmitted wirelessly via a small transmitter attached to the shirt to a smartphone, personal computer, or other similar device and then sent via the Internet to a server for waveform analysis.
Business resources management	Health management for staff with special duties	"Visualized object"	Manage workload and fatigue during working hours by analyzing and monitoring electrocardiographic waveforms of the employee to avoid assigning excessive work and to trigger an alarm if the person is at risk of becoming dehydrated or some other form of poor health. Because there is a close relationship between variability in changes in heart rate and things like autonomic nerve function and stress, it should be possible to estimate levels of stress and relaxation, and to intervene at an early stage if a tendency toward mental illness is indicated.
Business resources management	Health management for staff with special duties	Expected benefits	By encouraging staff to take a break when they show abnormalities such as excessive stress or fatigue during work, it should be possible to prevent them from continuing to work in a condition that is dangerous for their job. Furthermore, if early symptoms of mental health or other illness are identified, these can be prevented through early intervention.
Business resources management	Health management for staff with special duties	Challenges and issues to consider	While conventional electrocardiograph machines are attached to the skin using electrolyte paste to record heart rate, electrocardiographic waveforms, and other parameters, there is a need to verify in terms of the reliability of sensor technology that measurements can be made with the same level of accuracy as in the past. There is also a need to verify how much the environment in which the sensors are used influences their accuracy. In terms of privacy considerations, investigation is also needed into operational rules, such as measures for ensuring that biological information about staff is only available to industrial doctors. There is also a need for maintenance measures such as improving durability.

ETC: electronic toll collection

of different activities in the future, it is inefficient for each government institution to set up its own infrastructure for this purpose. Meanwhile, given that large amounts of data are now being generated and collected by private-sector companies and others, it is important to include consideration for utilizing this private-sector data when investigating what form the provision of infrastructure should take.

CONCLUSIONS

This study has demonstrated that a number of different government activities are potentially able to utilize the sensor technology that makes the IoT possible. This includes not only improving the productivity of tasks previously conducted manually, but also opens up the potential for new operational practices by monitoring the movement and other information about large numbers of people and objects in ways that would be impractical if performed manually.

Nevertheless, the study also identified a number of technological, systemic, and organizational challenges and considerations to bear in mind when introducing this sensor technology in practice. Hitachi looks forward to the public and private sectors working together on ways of overcoming these challenges so that, by making steady progress toward practical implementation, further advances can be made in the use of the IoT by government institutions.

ACKNOWLEDGMENTS

The study into the potential for using sensor technology in the public sector described in this article was aided by advice from an academic perspective on matters such as government use of IT from Hirokazu Okumura, a Visiting Professor at the Graduate School of Public Policy, The University of Tokyo, and from a practical perspective on such matters as the future direction and state of implementation of Japan's IT policy from Kenji Hiramoto, Executive Adviser for Chief Information Officer (CIO) of the Ministry of Economy, Trade and Industry. Advice and assistance were also received from the staff of The Institute of Administrative Information Systems during the period of the study, including discussion of the study's subject matter and report summaries. The authors would like to take this opportunity to express their gratitude.

REFERENCES

(1) M. Ai et al., "Next Generation Sensor Handbook," Baifukan (Jul. 2008) in Japanese.
(2) M. Nishio, "Public Administration [Revised Edition]," Yuhikaku Publishing (Apr. 2001) in Japanese.
(3) "Government Organization Chart (FY2014)," edited by Institute of Administrative Management (Oct. 2014) in Japanese.
(4) "Independent Administrative Corporations and Statutory Corporations (FY2013)," edited by Institute of Administrative Management (Jan. 2014) in Japanese.

ABOUT THE AUTHORS

Hiroyasu Takagi
Public Service Consulting Division, Hitachi Consulting Co., Ltd. He is currently engaged in consulting services relating to IT solutions for the operation and maintenance of social infrastructure, especially highways and so on.

Tadashi Mima
Public Service Consulting Division, Hitachi Consulting Co., Ltd. He is currently engaged in consulting on open data, big data, the national ID system, medical informatics, privacy and so on. Mr. Mima is a member of the Institute of Electronics, Information and Communication Engineers (IEICE), Japan Association for Medical Informatics (JAMI), and The Society of Socio-Informatics (SSI).