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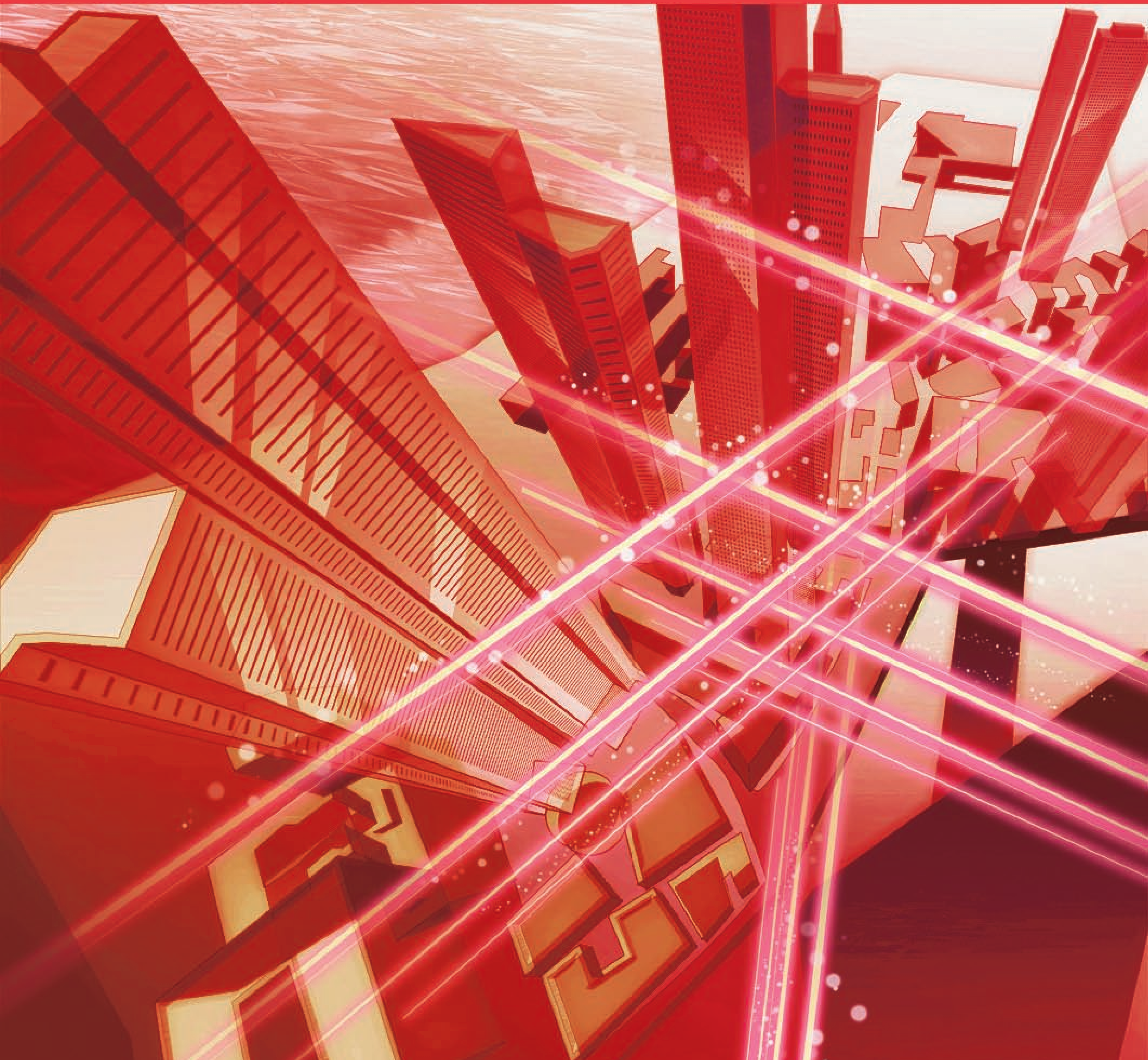
2011



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No Longer Just a Japanese Telecom Operator—Becoming a Global ICT Service Company

Noritaka Uji
NTT Representative Director and Senior Executive Vice President

Overview
For our opening interview of 2011, we had the pleasure of talking again with Noritaka Uji, NTT Representative Director and Senior Executive Vice President, who has been a great promoter of service creation in the NTT Group. We asked him about NTT's global expansion, which has already begun, and this year's strategy for the NTT Group, which supports the development of a ubiquitous broadband society.

Coming to fruition in 2011: the NTT Group Medium-term Management Strategy

—Last year, with the strong yen, there was little good news for Japan. What will this year be like? Please tell us your thoughts on this, beginning with your objectives for this year.

Well, last year was certainly very difficult, what with sluggish exports due to the strong yen and the slow growth of domestic demand. However, lackluster economic conditions do not mean that there can be no healthy and active areas in the economy. This year can be made into a vibrant one through great ideas and techniques. For us, this means information and communications technology, or ICT. I think that there are many areas where NTT, as a leading ICT company, can be active in helping to expand the economy and solve social problems. This year, I would like to accelerate our efforts in service creation, which we have been promoting for the last few years, and put even more energy into true global expansion.

Today, all kinds of services are appearing as part of the worldwide trends of service convergence and paradigm shift. One example is the convergence of broadcasting and communications as in video delivery over communication circuits and *One Seg* (one segment) television broadcasting on mobile phones. Furthermore, as your readers probably know, a paradigm shift from *owning* to *using* is now taking place with the coming of cloud computing.

New technologies and services that drive such service convergence and paradigm shifts are born through various types of collaboration. Inside Japan, there is of course collaboration among different industries, but I would also like to take up the challenge of achieving great developments in technologies, services, and even the economy through international collaboration that can take on various forms.

Further expansion of the broadband network

—This year looks to be a very dynamic one. Could you give us some specific examples of this year's

activities?

So far, we have been working on expanding the reach of the broadband network through fixed systems like the Next Generation Network (NGN) and fiber to the home (FTTH) and mobile systems like 3G (third generation) and Long Term Evolution (LTE). Japan's broadband network has become the world's fastest and cheapest by applying optical and wireless technologies cultivated over many years and promoting cost-reduction technologies. In Japan, optical broadband covers about 90% of the country, and the NGN coverage area is scheduled to encompass most of the existing optical area by March 2011. In addition, the Xi (pronounced crossy) mobile high-speed broadband service based on LTE was launched in Japan in December of last year.

I take great pride in the ability of our broadband network to satisfy our customers though its high-speed, large-capacity, high-reliability, and low-cost features. But we cannot stop here. It is also important that we ask ourselves: "What kind of services and what kind of value can we provide our customers by exploiting this infrastructure?" To this end, we are actively promoting the provision of services using both the fixed and mobile broadband networks.

Toward new lifestyles through full-scale development of video, Home ICT, and cloud services and promotion of fixed-mobile convergence

—What services are you contemplating at present?

I'm thinking of services that make maximum use of broadband capabilities. In particular, I would like to take the video, Home ICT, and cloud services that we have already been promoting to even higher levels while also planting seeds for new services.

Hikari TV, a video-delivery service using an optical IP (Internet protocol) network, already has more than 1.2 million users, and this number is expected to climb to about 1.4 million by the end of fiscal year 2010. This service gives users access to retransmissions of digital terrestrial broadcasts, multichannel broadcasts, and video on demand. And in 2010, we launched three-dimensional (3D) video delivery, a remote scheduling service using mobile terminals, and IP retransmissions of broadcast satellite programs. In 2011, there are also plans to begin trials centered on NTT Laboratories for a full high-definition (HD), 3D video delivery service as part of our ongoing efforts to provide more convenient and enjoyable services.

Furthermore, on the business scene, we announced Hikari Conference last year as a common brand for high-quality video communications. One product we launched under this brand is RiscaVision, a full-HD-quality videoconferencing system using the NGN. Here, by using high-quality networks and the latest video coding techniques, we are achieving a level of quality that makes users feel as if they are really sharing the same space. From here on, I would like to pursue the realization of high-quality multipoint connections that bring together even more people and locations, and I would like to make such advanced services available to general users as well. For example, I think it would be very useful to expand connections between people and between people and their family and home regions, such as by connecting grandparents and grandchildren living in homes far away from each other.

As for Home ICT, we have been forming alliances and conducting joint experiments with many companies since December 2009, especially major home-electronics and office-equipment makers. With basic technology-verification experiments completed, we began field trials in November 2010. Genuine services will finally commence from spring 2011. The number of subscribers to various Home ICT services that are already being provided is increasing steadily. These include support for configuring personal computers and network devices and a remote support service for responding to user problems. Looking forward, we can see Home ICT becoming a home control center that serves to improve the quality of life and help solve diverse social problems in relation to home security, video sharing, medical treatment and healthcare, education, the environment, and other areas. This Home ICT technology can also be expanded as office ICT to the large number of medium-sized and small companies in the economy, and I would like to push this forward.

Then there's the cloud! I would also like to focus our attention on cloud computing. As you know, the NTT Group has been developing platforms and networks for achieving clouds as well as applications to run on those platforms in collaboration with partners.

At NTT Laboratories, important large-scale distributed processing platforms and operations and management technologies are now being developed toward expansion of cloud computing with an emphasis on keywords like *open*, *secure*, *large-scale*, *distributed*, and *eco*. In this regard, a research and development (R&D) cloud that includes these developments is scheduled to be launched in 2011. At first, this cloud will be used for researching and developing a variety of services and technologies. In time, however, I would like to see it linked with business enterprises and outside research institutions to further expand the use of cloud computing. I would also like to apply the know-how and experience that we gain here to corporate clouds and government, medical, healthcare, and educational applications to construct a safe and secure social-infrastructure cloud.

—It appears that life is becoming more manageable and enjoyable and that lifestyles are changing because of these services.

That's right. And by furthering the development of video, Home ICT, and cloud computing, we will soon be entering an era where it will be commonplace for users to seamlessly access their daily living and working environments without regard to place or type of terminal. The use of tablet personal computers (PCs) to read electronic books and perform other tasks is already spreading, but it is also becoming possible to partake in e-learning, to view movies or sports programs, or to receive recommended services using high-quality video from PCs, tablet PCs, or smartphones connected to school or home networks. This seamless access should reduce the stress that users feel when making a new connection with a different terminal. In 2011, fixed-mobile convergence (a service format converging mobile communications and fixed-line communications) that includes the broadband network, upper-layer services, and various sorts of terminals will become all the more important.

Accelerating R&D for enhanced service creation

—These services are already quite amazing, but are they still evolving?

Service creation is endless! This is because simply being able to provide a service is not the same as making it easy to use and providing it at a reasonable price. The mobile phone, for example, has evolved from a car phone to a shoulder phone and then a handset and has even become a fashionable product. All sorts of functions are now appearing on mobile phones such as concierge services and mobile wallet (Osaifu-Keitai), and nowadays, the mobile phone is simply becoming one's mobile or smartphone, which is coming to be used in all facets of everyday life.

Mobile phone technology is evolving much faster than I originally imagined. From a global perspective, it is amazing how the number of mobile subscribers has surpassed fixed-line users in Japan, how fast and inexpensive broadband connections have become, how computer performance and memory capacity have significantly increased, and how large volumes of data can now be uploaded to servers. Even though I understand how all this is technically possible, the speed at which it has been achieved is truly remarkable.

—As a service provider, it would seem that NTT is feeling pressure to provide services at breakneck speeds.

Yes, that's right. I'm always telling researchers and developers that "Speed is of the essence!" and that "Today's R&D pace is not good enough—we have to move faster!" If it were only NTT providing services, perhaps the current pace would be sufficient, but this is a market with all kinds of global players in which many technical innovations are being made.

Here, it's the cloud that is attracting lots of attention. Participants in cloud services include computer and network-device makers, network-related start-up companies, the software industry, and even telecommunications operators like NTT, so the mechanism of competition is changing radically. It is exactly for this reason that technical innovation and the development of competitive products are being forced to move faster. We must respond to this sort of competition too.

NTT began as a Japanese telecommunications operator, but it wants to become an enterprise that provides ICT technology and services on a global basis. I see NTT as a company that, while expert at developing technology, also knows how to use that technology and to provide it in the form of actual services. NTT R&D includes about 6000 researchers throughout the NTT Group. It has a world-renowned reputation and is the source of NTT's competitive power and growth. Of the research projects that are now being undertaken and technologies that are now being provided, perhaps some of them are not progressing very well, while others are perhaps ahead of their time. Needless to say, we must make an effort to provide products more appropriate for customers and the times by, for example, improving cost performance and ease of use. There are still many things that we can do to provide customers with good services while competing globally. The level of quality demanded by Japanese consumers, by the way, is very high in a good sense (laughs). So a good scenario, I think, is to make Japanese technology grow and to then take this technology overseas with an eye to global expansion.

Becoming a global ICT service company

—In this regard, I've heard that NTT provided technology for the World Cup held in South Africa.

Yes. We provided video transmission equipment for

the 2010 FIFA World Cup in South Africa. This equipment was used by 20 broadcasting stations around the world to deliver high-quality video to 60 countries. It is an example of the service convergence between communications and broadcasting that I talked about earlier. More recently, our technology has been used at the rescue site for the Chilean miners trapped by a cave-in. Do you remember how a videophone was used to check on conditions down below? That videophone used NTT technology. Speaking of Chile and mining, NTT teamed up with CODELCO, a Chilean state-owned mining company, in 2006 to establish a joint business venture called Micomo to expand NTT R&D products to the mining industry, which is outside NTT's traditional line of work. Micomo was the company that passed an optical fiber through a hole opened up from the surface at the rescue site and installed a videophone. Since cave-ins and other types of accidents have always been a possibility in mines, we established Micomo thinking that safety management and means of communication are absolute necessities underground. I am extremely pleased that NTT video-communication technology proved to be useful at the rescue site.

—I can see that NTT technology is establishing a global presence. Please tell us about NTT's global strategy for the future.

Talking about the global situation, merger and acquisition (M&A) activities with overseas firms have become a trend in Japan as a result of the strong yen. NTT is no exception to this trend—the reality is that the Japanese market is rapidly shrinking, and in the end, global expansion is essential to the company's growth. The worldwide market is still growing, and it's simply too good an opportunity to pass up. NTT Group's overseas sales target for fiscal year 2012 is $10 billion, which shows how the currency unit for this forecast has been changed from yen to dollars. This is certainly one example of how NTT is not just a Japanese company but one that is expanding globally.

The fact is, NTT is actively promoting M&A. Dimension Data, which we purchased in 2010, is a South African company that became a group company under the NTT holding company last autumn. We are expanding our business throughout the world including South America, Africa, the Middle and Near East, and Australia, which I think is opening up new, fresh markets for NTT. In addition, Keane, Inc., which was purchased by NTT DATA, is a leading player in the systems integration business in the USA, and we think that it should provide the NTT Group with a solid foothold in the American market.

Although it is a Japanese communications company, NTT is expanding its business regions and content with an eye to becoming a global ICT solutions company and service provider. With these big changes, NTT will finally make a genuine move into the outside world.

It is visionary and pioneering for a non-manufacturing telecommunications company like NTT to expand globally other than in the network business and to broaden its business line. The NTT Group boasts multifaceted group power that includes upper-layer services, solutions, construction and power, and R&D in addition to fixed and mobile communications businesses, and I think that these comprehensive abilities should be demonstrated.

By the way, around the time that Nippon Telegraph and Telephone Public Corporation became NTT, I read with great interest a book entitled "In Search of Excellence". The word excellence in this title referred to a hands-on customer-first policy that companies should adopt. I want NTT to be an *excellent company* and its individual units to be excellent as well. It should be a company that enjoys a difficult challenge, whose customers are highly satisfied, and that is well respected for its achievements. This is a year of great challenges that will stimulate NTT Laboratories and the entire NTT Group. Just watch us now!

Interviewee profile

■ Career highlights

Noritaka Uji joined Nippon Telegraph and Telephone Public Corporation (now NTT) in 1973. He handled tasks related to NTT privatization and startup business development. In 1988, he moved to NTT DATA, where he was initially in charge of planning and developing information systems for private enterprises. He then served in various managerial roles including Director of the Next-Generation Information Services Sector, Senior Vice President and Director of Business Planning, and Senior Vice President and Director of Enterprise-related Sectors. Building on these experiences, he assumed the post of Senior Executive Vice President in 2005. He began serving in his present position in 2007.

Trends in Lifelog Applications and Progress at NTT R&D

Masanobu Abe and Takaki Ichimori†

Abstract

In this article, we describe our view of the advantages of lifelogs and survey current services that utilize lifelogs. We also outline research and development (R&D) efforts in lifelog technologies at NTT Laboratories by introducing the other six feature articles in this issue in terms of lifelog processing steps.

1. Introduction

Amazing advances have been made in recent years in the broadband environment, consumer electronic devices, and mobile phones. For example, users can now view the huge amount of video content on the Internet on their own televisions (TVs) using broadband connections, and weblog (blog) sites are exploding in number as niche information overflows in an unforeseen way. Microblogging, which involves small content, is a service that has appeared recently on social networks such as Twitter. It enables public figures and celebrities, amongst others, to share their musings and activities in nearly real time. Moreover, smartphones let users access the huge amount of information on the Internet in the same way that personal computers do but from wherever they please at anytime. New electronic devices are also appearing in society. Digital photo frames enable digital photographs to be shared over the network and e-book readers with communication functions let users purchase and read books anytime and anywhere. The growth of such services over the last few years has been nothing short of remarkable.

At the same time, there is still some doubt as to whether users will be able to fully enjoy these novel services. Searching for and retrieving desired content and meaningful information from the massive Internet is troublesome. It is also difficult to learn how to use a multifunction electronic device while referring to a bulky manual. Even though an electronic device may be equipped with a variety of convenient functions, the user may not be able to make full use of them unless helpful information is readily at hand. We believe that the means of solving or easing this problem can be found in the use of a *lifelog*. A lifelog is a digital record of an individual's activities accumulated over the long term. It may include a history of web pages visited and keywords input to search engines, as well as content created by the individual such as documents prepared using a word processor and photographs taken with a digital camera, electronic records of the individual's weight and calorie intake, and the history of sent/received emails and incoming/outgoing telephone calls. It has also become possible in recent years to obtain GPS-based location information and use smart cards to record the train stations used for commuting, the products purchased at convenience stores, etc. (GPS: global positioning system). These capabilities suggest the possibility of constructing lifelogs that are closely associated with daily activities. How then, can such an extensive and detailed lifelog be useful?

2. Usefulness of lifelogs

User characteristics have traditionally been obtained in the form of demographic attributes such as age, sex, and home region (**Fig. 1**), but a lifelog can provide more detailed knowledge about the user. For example, an individual's web browsing history and

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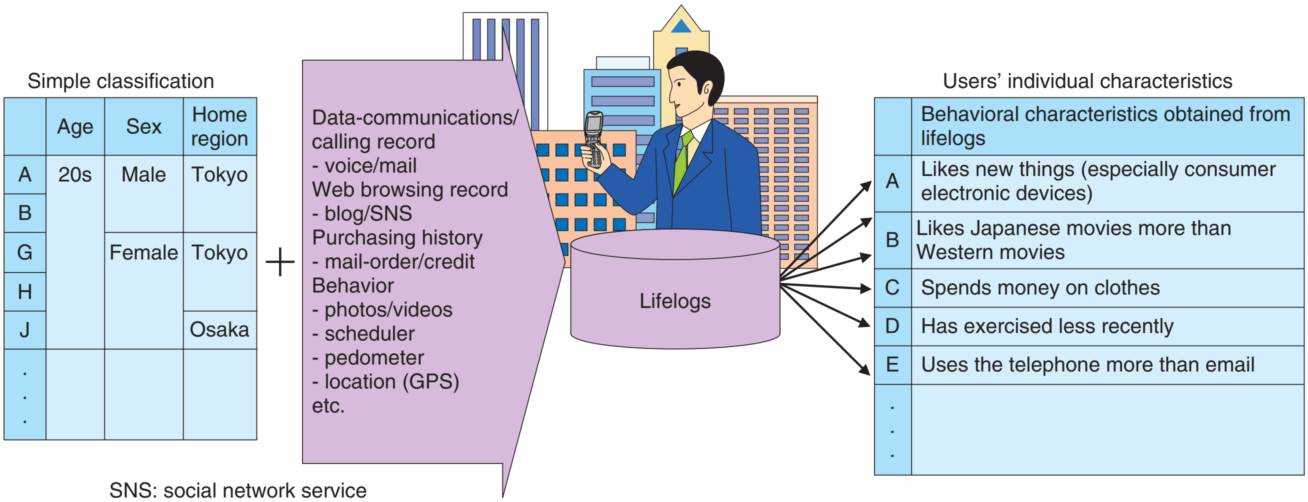

Fig. 1. Lifelogs.

e-commerce history can reveal whether that person has an eye for new electronic consumer products, likes Japanese movies more than Western movies, or spends money on clothes. Preferences such as these can be used to make preliminary selections from the huge amount of content and information on the Internet so that the user can easily and enjoyably obtain what he or she needs. Device usage history could be used in a similar manner. If the way in which the user uses a device is known and if functions that the user tends to use can be selected beforehand, it should be much easier for the user to make full use of a multifunction electronic device. In a similar manner, referencing the tendencies of other users who have similar likes and dislikes and making product and service recommendations accordingly should make it possible to provide information that the user might otherwise never notice. Such lifelog usage enables the user to be provided with appropriate information and services.

Building a lifelog over the long term in a continuous fashion is a powerful technique for determining user preferences. For example, let's assume that a user has been watching soccer matches involving the Japanese national team during the FIFA World Cup. This information in itself cannot be used to determine the extent to which the user is a soccer fan. However, if the user watches soccer matches every week and it is known which teams competed in them, the soccer team that the user is a fan of can be surmised. Similarly, the team that a user follows over a period of several years can be investigated, and if the user's favorite team is found to have changed, a connection with the transfer of a particular soccer player can be surmised. If, on the other hand, the user almost never watches weekly soccer matches, it can be surmised that the user is only a soccer fan to the extent of watching the World Cup. Analyzing a user's lifelog obtained over the long term can also be useful in other ways, such as for determining habitual behavior that appears periodically. In short, using user tendencies such as those described above to predict user behavior should enable information that the user truly needs to be provided in a timely manner. In the following section, we take a look at current services that make use of lifelogs.

3. Services using lifelogs

To understand how lifelogs can be used, let us consider two axes (**Fig. 2**). The first draws a line between individual behavior in the real world and that in cyberspace, while the second separates usage confined to an individual's lifelog from collective usage of the lifelogs of many people. Traditional health management data such as weight, height, and blood pressure constitutes an example of a real-world log. In this regard, the recent appearance of wearable devices such as pedometers is making it possible to collect data closely associated with the user at all times. And in sports training, GPS-based devices are making it possible to record jogging routes. Logs such as these can be used in the fields of health management and physical training to enable user-specific

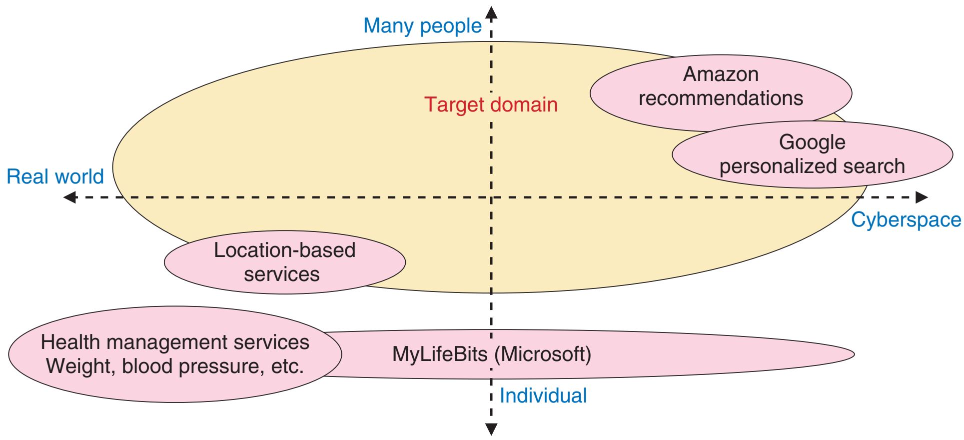

Fig. 2. Classification of lifelog services.

advice to be given. In short, the use of these logs is confined to the individual. Recently, some users have been uploading their individual records to net-based communities to engage in friendly rivalry with other members of the community in dieting, training, etc. However, log usages such as these are not collective ways.

MyLifeBits [1] is an example of using a lifelog that accumulates a wide array of information over time about a specific individual. It is essentially the first research project to concentrate on lifelogs and is based on the concept that *various types of information related to an individual should be managed and used by that person in an integrated manner*. MyLifeBits inputs almost all records related to an individual's activities, from digitally created documents and email and incoming/outgoing telephone calls to photographs and videos taken by that person and scanned images of business cards. The MyLifeBits system is equipped with high-speed search functions that simplify the task of looking back at one's personal history.

In contrast, Amazon's product recommendation system [2] is an example of assembling and using the lifelogs of many people. This system makes recommendations in the manner of *people who bought this book also bought these books* and *people who bought this product also bought these accessories*. It accumulates the purchasing trends of many users and gives advice to customers who are thinking of purchasing the same products. Since some users may simply forget to purchase accessories or may just not be knowledgeable about necessary items, this service can be very helpful. This sort of recommendation service that also includes search advertising is proving to be popular at present. Such services are successful examples of log usage, and they are helping to attract interest in the use of lifelogs. The data accumulated in the logs of these services relates to user activities in cyberspace, such as web history, search terms, and purchased product history. Logs of these types use the logs of many people and log data is accumulated continuously over the long term. A key point here is that these services are structured in such a way that the data is obtained and stored not through the efforts of the users themselves but by a background process unnoticeable to users.

Location information has recently been attracting attention as the basis for real-world logs. This interest has been driven by the spread of mobile phones equipped with GPS functions. For example, information related to the user's current location can be given priority for display when the user performs a search from a mobile phone, and photographs taken with a mobile phone can be tagged with location information. These GPS-related services relieve the user from performing extra operations and are proving to be popular as a result. Taking user context into account in the form of location information makes the mobile phone all the more convenient.

As described above, recommendations that take the user's preferences and context into account are being well received. The benefits for the user include new discoveries that could not be found on one's own and the receiving of services and information without the burden of having to do extra work. There is no doubt that cyberspace logs are making a big contribution to the realization of these benefits. In the real world,

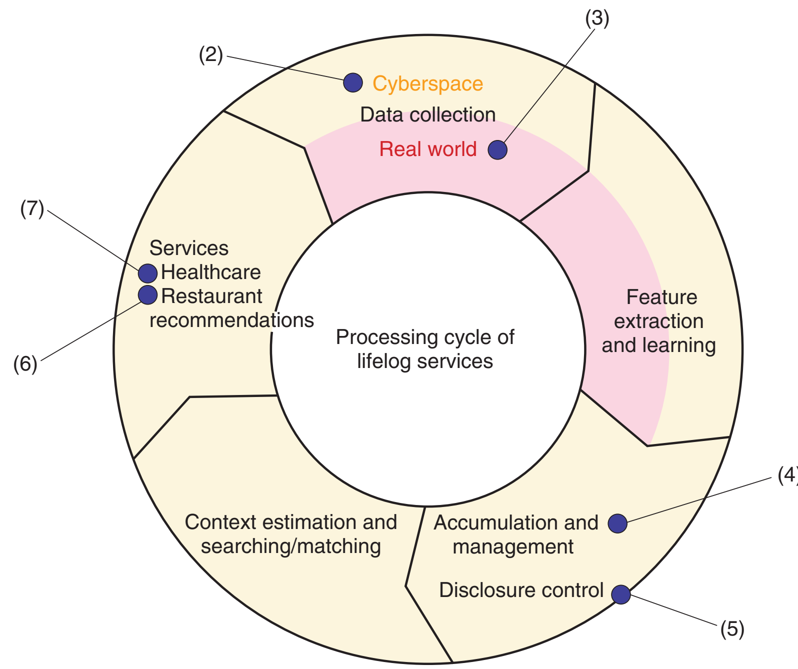

Fig. 3. Correspondence between feature articles and lifelog processing cycle.

moreover, the appearance of mobile devices raises the possibility of acquiring data closely associated with the user. In a manner similar to the way in which cyberspace logs based on many people are bringing real benefits to users, we envision that real-world logs based on many people or a combination of real-world and cyberspace logs based on many people can be a key to the provision of novel services.

4. Lifelog processing cycle

Service processing making use of lifelogs is shown in **Fig. 3**. This processing flow must be in the form of a loop so that user satisfaction with services can be continuously fed back to the system, and services can adapt to user needs in a process unnoticeable to users. Using lifelogs requires diverse technologies, and developing all of them on one's own is not feasible. To provide compelling services, we plan to enhance those technologies that we specialize in while appropriating other suitable technologies. Below, we describe the roles of the technologies covered in the other feature articles in this issue.

In lifelog construction, data should be collected over as long a period as possible and in as many varieties as possible. More data enables a greater number and variety of user tendencies to be uncovered.

The second article, "Personal Computer Operation History Data Collection System—Memory Retriever" [3], introduces technology for collecting a history of user actions on a personal computer ((2) in Fig. 3). A user can perform a variety of tasks on a personal computer such as accessing websites, creating documents, and sending and receiving email. The objective here is to acquire as many user tendencies as possible by collecting all sorts of user actions across various types of tasks.

The third article, "Lifelog Remote Control for Collecting Operation Logs Needed for Lifelog-based Services" [4], investigates the use of a remote-control operation log as a real-world lifelog ((3) in Fig. 3). In this regard, a mechanism that can accumulate lifelog data in the background is important; if it takes considerable effort to maintain such records, it will be difficult to collect lifelog data in an ongoing manner over the long term. Remote-control operations have become essential to daily life, which makes them a convenient means of obtaining lifelogs in an incidental manner. Specifically, as remote controls can be used for selecting TV programs, setting the temperature on an air conditioner, turning lights on and off, etc., such operations can be used to understand the lifestyle of an individual in terms of personal likes and dislikes, preferred indoor temperature, bedtime, and other characteristics.

The fourth article, "Data Stream Management Technology for Accumulating and Processing Lifelogs" [5], introduces a data management system for the realtime processing and saving of diverse types of data associated with many people ((4) in Fig. 3). Since lifelogs consist of the records of individuals, the number of users can be expected to increase over time, which calls for a mechanism that can flexibly expand with the system scale. Moreover, services that make use of lifelogs should be current, so realtime processing is necessary. The system introduced here meets both of these requirements.

The fifth article, "Social Science Research Approach for Lifelog Utilization" [6], concerns the issue of privacy, which always arises when lifelogs are discussed. It introduces a means of safeguarding privacy on the twin bases of legal systems and technologies ((5) in Fig. 3).

The remaining two articles introduce two key services. Specifically, the sixth article, "Restaurant Recommendation Service Using Lifelogs" [7], describes a service for recommending restaurants and presents the results of an evaluation experiment ((6) in Fig. 3). This service is one step ahead of existing services of this type since it predicts user behavior and also takes into account not only what the user enjoys eating but also what his or her companions enjoy.

The seventh article, "Prospects for Using Lifelogs in the Medical Field" [8], describes a service that makes use of a person's vital-signs data and activity-related data in everyday life ((7) in Fig. 3). This service is especially convenient as it connects with network services for viewing medical charts in healthcare institutions.

5. Conclusion

We described the concept of lifelogs and outlined research and development (R&D) efforts in lifelog technologies at NTT Laboratories. While a number of services utilizing lifelogs have already appeared, this field is still in its infancy. It will become increasingly easier to build up lifelogs as an information infrastructure comes into place and devices progress. In future, we plan to continue our research efforts in this field with the aim of making lifelog usage more effective and convenient.

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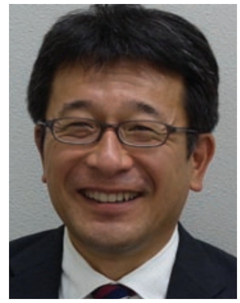
He received the B.E., M.E., and Ph.D. degrees in electrical engineering from Waseda University, Tokyo, in 1982, 1984, and 1992, respectively. He joined the Yokosuka Electrical Communications Laboratories of Nippon Telegraph and Telephone Public Corporation (now NTT) in 1984. From 1987 to 1991, he worked at ATR Interpreting Telephony Research Laboratories. In 1989, he joined the Laboratory Computer Science, MIT, USA, as a visiting researcher. From 2007 to 2010, he served as an Executive Manager, Senior Research Engineer, Supervisor of NTT Cyber Solutions Laboratories. He has been a professor at Okayama University since 2010. His research interests include digital speech processing, home networking, consumer electronic appliances, data mining algorithms for lifelogs, and human interfaces. He is a member of the Acoustical Society of Japan (ASJ), the Institute of Electronics, Information and Communications Engineers of Japan, IEEE, and the Association for Computing Machinery. He received a Paper Award from ASJ in 1996. He is co-author of "Recent Progress in Japanese Speech Synthesis" (Gordon and Breach Science Publishers, 2000).



Takaki Ichimori

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He received the B.E. and M.E. degrees from Hokkaido University in 1984 and 1986, respectively. He joined NTT in 1986. From 1986 to 1996, he worked at NTT LSI Laboratories. From 2003 to 2008, he worked at NTT Resonant Inc. From 2008 to 2010, he worked at IPTV Forum Japan. He has been an Executive Manager of NTT Cyber Solutions Laboratories since July 2010. He is a member of the Information Processing Society of Japan.

Personal Computer Operation History Data Collection System—Memory Retriever

Akimichi Tanaka† *and Tadasu Uchiyama*

Abstract

In this article, we introduce our system called Memory Retriever, which automatically collects the history of a user's operations on a personal computer and explain its functionalities.

1. Introduction

With advanced broadband access services becoming more widespread, people are spending more time on computers searching for information, shopping for personal goods, and engaging in other activities. The history of a user's computer operations is a valuable source of information because it reflects his or her likes and tastes. However, most data of this type is currently not used, but just wasted. Therefore, we have developed a system, called Memory Retriever, that automatically collects and accumulates personal computer (PC) operation histories for subsequent use in other advanced services. Some usage examples of users' PC operation histories and those of their colleagues and third parties are given in **Table 1**. Each history can be used for many purposes.

2. Requirements

We considered whether or not to require the installation of an application on each user's computer. Without a dedicated application, only a limited set of historical data such as Internet accesses can be acquired from web server logs or proxy server logs, as indicated in **Table 2**. To allow more detailed information to be obtained, we chose the approach that does require the installation of an application on the user's computer because we think that the advantages outweigh the disadvantages.

3. System architecture

An overview of our system is given in **Fig. 1**. The system basically consists of the client PC (C-PC) and the history collection server (HCS). The former is currently implemented using Windows XP or Windows Vista. The latter runs Cent OS.

C-PC captures the operation history and sends the data to HCS, which includes the following functionalities.

(1) Browser add-on:

It retrieves the browsing history via a web browser add-on. We have developed plug-ins for Internet Explorer and Firefox.

(2) History retrieval module:

This module consists of a history retrieval plug-in and a history collection program. The former captures the user's operation history and writes the data into operation log-files. The latter accesses and processes the data written in the operation log-files and stores the results in the operation history database. The plug-in has a structure that simplifies the handling of additional user input/output devices such as touch-pads. The browser plug-in receives data retrieved by the browser add-on and writes the received data in operation log-files.

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Table 1. History usage examples.

History	Usage examples
User's own history	A user can analyze his or her own computer behavior by reviewing computer operations objectively.
Colleagues' histories	Employees can avoid redundant searches and improve their work efficiency by sharing online search activities.
Third parties' histories	Trends of various groups can be defined by categorizing histories by age and gender,

Table 2. History collection methods.

Method	Browsing web pages		Operations other than web browsing	Easy PC setting	Load on PC
	URL retrieval	HTML retrieval			
PC application	Good	Good	Good	Poor	Poor
Web server log	Poor (good only for own website)	Poor (good only for own website)	Poor	Good	Good
Proxy server log	Good	Good (not available on http websites)	Poor	Good	Good

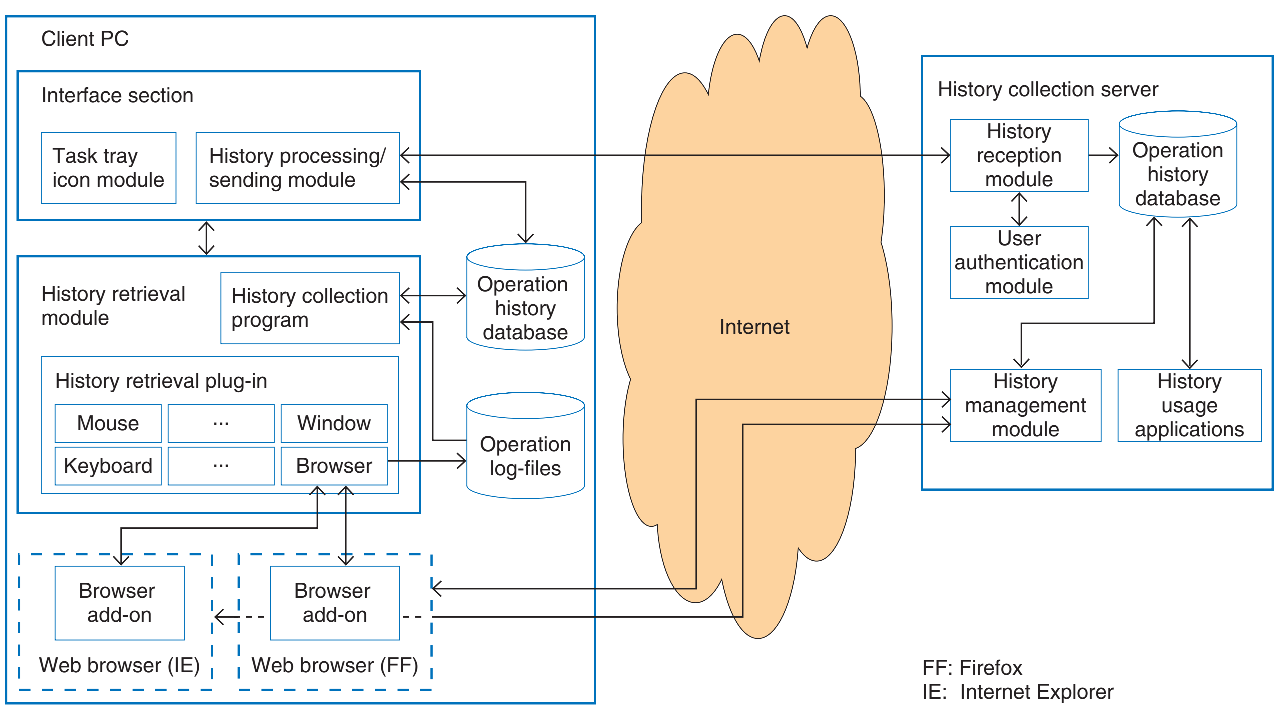

Fig. 1. System architecture.

(3) Interface section:

This section consists of the task-tray icon module and the history processing/sending module. The task-tray icon module shows icons that are always in the task-tray and acts as the starting point of the interface with the user. The history processing/sending module

Table 3. Retrievable history data.

Plug-in	Retrievable data
Mouse	Double click, button down/up
Keyboard	Key down
Window	Title, application name, name of file in use, thumbnail image
Browser	URL, HTML file, thumbnail image, title, referrer, search word, anchor text
Clipboard	Copy, paste
Printer	Start, end
File	Copy, move, erase

reads data from the operation history database and sends it to the history collection server. The module also extracts keywords used on search engine websites such as "goo" as well as the anchor text of clicked links. Data that has already been processed is erased after a preset time.

HCS receives the operation history sent via C-PC and accumulates the data in its database. It has the following structure.

(1) History reception module:

This section receives the operation history from C-PC and accumulates it in its operation history database.

(2) Operation history database:

This stores the operation history data sent via C-PC.

(3) User authentication module:

This module checks user names and passwords to ensure that a recently received operation history is associated with the correct user.

(4) History management module:

This module manages data in the operation history database.

(5) History usage applications:

Applications will be created to satisfy users' demands for how they want the acquired history to be used.

4. Retrievable data

Currently available plug-ins for operation history retrieval cover the mouse, keyboard, windows, browsers, clipboard, printers, and file access. History data that can typically be acquired by these plug-ins is listed in **Table 3**. Each data item is timestamped. Users can access the history management module on HCS via an ordinary web browser. An example of a web browsing history is shown in **Fig. 2**. Each web browsing sequence is shown as one unit. The top row is the history of the actions performed between 16:54:08 and 17:18:21 on April 9, 2010. Thumbnails of web pages visited during the time period are shown (partially). Users can access detailed information about each page by clicking one of the time periods shown.

5. Unique functions

Our system has the following unique functions.

(1) Scalable history retrieval

Our system can easily handle additional devices whose history is to be made available for retrieval if a history retrieval plug-in is created and placed it in a folder.

(2) Detailed information about web browsing

It can acquire not only URLs (uniform resource locators), but also HTML (hypertext markup language) files, thumbnails, and HTML files of small frames on frame pages. It can also retrieve search words as well as anchor text.

(3) Privacy protection

Since web browsing information may include users' private information, two functions are provided to protect their privacy.

- Protected-word anonymization function:

When words present in a protected-word list are included in a received HTML file, they are anonymized by being converted into XXX before being sent to HCS.

- URL filter function:

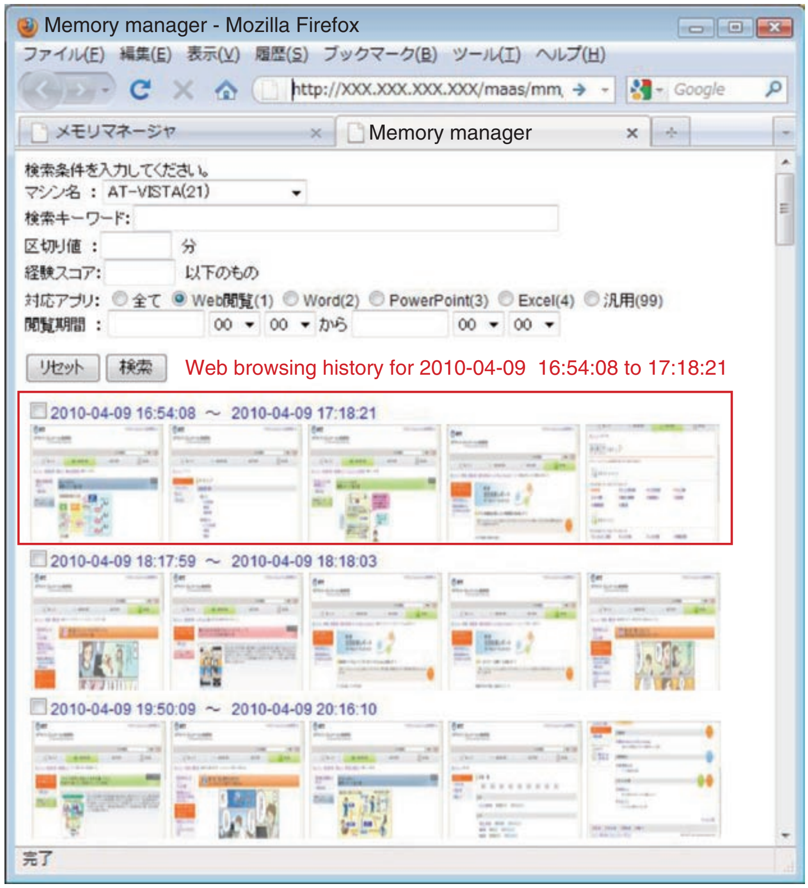

Fig. 2. Example of web browsing history.

A white list and a black list are provided. History data is stored when users are browsing URLs on the white list but not when they are browsing ones on the black list.

(4) Greater amount of retrievable window information

As Table 3 shows, the name of each application and file used can be retrieved via a window plug-in. Although it does not show detailed information about each application, it shows rough information, such as file opening/closing times, which means that most PC operations can be understood.

6. Advanced usages

Below we give three examples of how retrieved history data can be used.

(1) Own behavior review

A user can understand his or her computer behavior objectively, as shown in Fig. 2, by reviewing the PC's web browsing operation history. As a result, the user may realize that he or she is spending too much time on a particular web page or has stopped visiting certain websites, which might lead to behavior changes for better computer use.

(2) Knowledge sharing at the office

Since operating histories are collected on HCS, office workers might feel uncomfortable about all the web pages that they have visited being logged in one location. Instead of identifying web pages individually, it might be better to disclose a single web page that visualizes only statistical information about the computer operations of all the workers. Such a web page could include ranked lists of the most-used search words or web pages where people stayed for the longest time. The usage flow for data sharing is

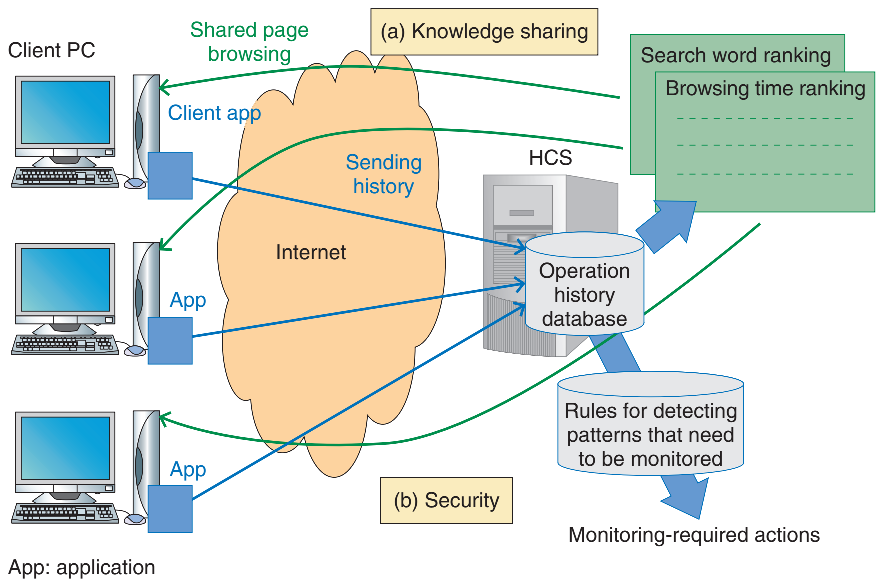

Fig. 3. Advanced usage.

shown in (a) in **Fig. 3**. The sharing of such knowledge at the office will help raise the efficiency of work.

(3) Security

In recent years, web-based computer systems have becoming common at many companies and municipalities across Japan, and browser histories are becoming more valuable as data sources. Our system allows a warning module to be implemented that will help prevent information leakage. This module will use predefined monitoring patterns to detect inappropriate operations such as company files being accessed and forwarded by web mail. The usage flow for security is shown in (b) in Fig. 3.

7. Future plans

We will continue researching ways of increasing the number of items whose history can be retrieved, including detailed operation information about popular Microsoft Office applications (Word, Excel, and PowerPoint), email, and USB (universal serial bus) memory. Considering that it may become difficult to display one complete history record when there are many items, we are developing a scoring method that will display only high-scoring items. We also plan to develop history usage applications that satisfy users' needs.

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Lifelog Remote Control for Collecting Operation Logs Needed for Lifelog-based Services

Tomoki Watanabe†, Youichi Takashima, Minoru Kobayashi, and Masanobu Abe

Abstract

In this article, we describe our concept of using personal remote controls to collect data for subsequent utilization and the remote control's user interface design, focusing on the technology that makes it possible, for the first time, to collect truly useful lifelogs.

1. Introduction

To provide lifelog-based services, we need to accurately estimate the user's preferences and behavioral patterns in daily life from various activities. The key to accurate estimations is gathering sufficient data to identify each user's likes and preferences. In recent years, various services that provide recommendations have been developed. They process data about the user's Internet access activities such as online shopping and visited websites. Other services process information about the user's location by defining *places* through a GPS (global positioning system) function. To use those services, however, users still need to register their likes and preferences in advance, but that is so inconvenient for users that their preferences and behavioral patterns can never be fully captured.

We believe that continuously receiving and storing users' lifelogs over long periods of time will yield a structure that can collect data more easily without imposing a heavy load on the user.

Our approach is centered on utilizing a personal remote control that each user carries and uses to operate all home devices. The operation data is saved within it and sent to service providers only when the user permits. In this way, each user's personal information can be protected.

In developing our lifelog collecting approach, we are focusing on two major points: (1) a remote control that allows users to control various devices and saves operation logs within itself and (2) an attractive interface that encourages users to use the remote control all the time. In this article, we describe the technologies underlying the lifelog collecting system and its user interface.

2. Information acquired from operation logs

The operation of home devices is assumed to reflect the user's free will choices. That is, those actions reflect the user's likes or preferences. For example, if the user turns on a television (TV) and selects a station that offers music programs, we can assume that the user is interested in music, whereas if it is a movie channel, we can assume that the user likes movies. If the user sets the air conditioner to 17°C everyday, we can assume that the user tends to feel comfortable at that temperature. When the user turns room lights on and off, we can determine what time the user comes home and goes to sleep. Such operation data is, we believe, a strong indicator of the user's likes, preferences, and behavioral patterns.

Below, we describe our ongoing work.

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3. Lifelog collecting system

NTT Cyber Solutions Laboratories has developed a lifelog collecting system that allows users to operate home devices from a single remote control. We targeted devices with infrared sensors because most modern home devices are equipped with such sensors.

The structure of the lifelog collecting system is shown in **Fig. 1**. As the remote control, we chose to use a smartphone because its operation screen is easy to customize.

Command relay devices, wirelessly driven by the smartphone, are set throughout the house so that the intended device can receive its control signal.

We use wireless local area network (WLAN) connections to link the smartphone to the command relay devices. To stabilize each WLAN connection and ensure that the control signals reach the intended device, we mounted the command relay devices on ceiling lights (**Fig. 2**). This arrangement allows infrared rays to be sent in eight different directions at the same time, which provides coverage over a wide area.

Remote control applications are written for each appliance and loaded into the smartphone (**Fig. 3**). Since each appliance uses a different remote control, the program creates a virtual remote control on the smartphone. The user selects the appliance and then presses the virtual keys to input the command desired. The corresponding signal is sent to the pre-set command relay device. The command relay device converts the signal into the appropriate control signal and then transmits the infrared signal. The command relay device nearest the device that the user wants to operate, such as the TV, should be selected as this makes signal reception more reliable. The smartphone automatically makes a list of available command relay devices, and the user can select the desired one from the list.

System implementation proceeds as follows.

(1) Connect all command relay devices to the home's WLAN.
(2) Connect the smartphone to the WLAN.
(3) Select each device (manufacturer and product) to be operated with the remote control and install the corresponding program in the smartphone.
(4) For each device, select the nearest command relay device and register it in the smartphone program.
(5) Repeat steps 3 and 4 for each device to be operated.

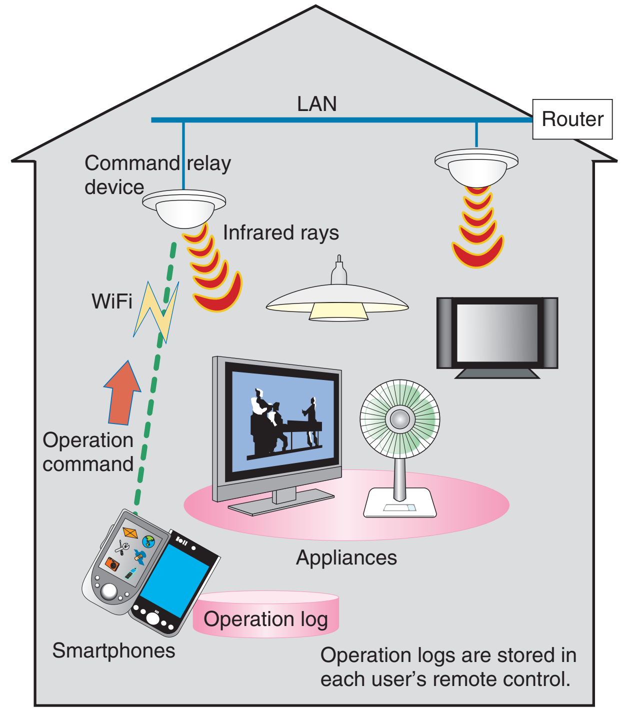


Fig. 1. Structure of the lifelog collecting system.

Fig. 2. Infrared repeaters in ceiling lights.

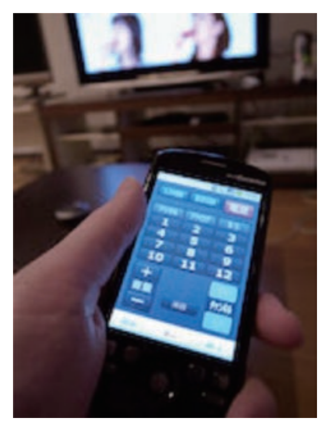


Fig. 3. Remote control applications are loaded on the smartphone.

(6) Activate the application for the device and operate the device via the virtual remote control on the smartphone. To operate another device, activate its application.

The user's remote control application operation data is first saved as logs on the smartphone. Those logs are sent to providers that offer lifelog-based services if the user allows the data to be sent.

4. Device status estimation from operation logs

The operation logs of each user can be collected individually by the lifelog collection system. Although the operation logs contain information about when and which button was pressed, it is difficult to know the status of each device accurately. For example, from an operation log entry that says "the user pressed the TV power button" on the smartphone, you cannot tell if the user turned the TV on or off. If the station 1 button was pressed, we can assume that station 1 was selected, but if the user used the channel up-down button to choose the station, you need to know which station was on before to figure out which station the user chose. Furthermore, new terrestrial digital broadcasting services offer more complicated programs in Japan. Two or three different programs are offered under a single channel button (**Fig. 4**). In such cases, it is very difficult to determine which channel the user selected from a single operation log.

We have been developing a method of estimating the device status as accurately as possible. It tracks TV status transition and checks the status transition against the operation log containing pressed buttons and the time lag between button presses. For example, if there is no record of any operations immediately after the power button was pressed, we can assume that the user turned the TV off. If the history shows some operations, such as adjusting the volume or changing channels, we can assume that the user turned the TV on. Moreover, from operation data for lights and air conditioners, we can estimate the user's lifestyle and behavioral patterns by knowing when the user turned lights on or off and what temperature was usually selected.

To obtain users' preferences and behavioral patterns, we have to estimate the status of each device from information acquired through operation logs. One option would be to determine the status from the device, but if we can determine each device's status through the remote control log, the usage range will be wider.

5. Attractive user interface that invigorates lifelog-based services

Since a personal remote control must be used for long periods of time to gather sufficient data for lifelog-based services, it must be easy to use.

5.1 "Coool" remote control

For prolonged use, the remote control should be easy to hold and fit comfortably in the user's hand. Buttons must also be easy to press. We developed the "Coool" remote control to satisfy these requirements (**Fig. 5**). It is round and each button is placed for easy access by the user's thumb. The rocker switch in the center can be pressed up or down and left or right. This allows the user to change display contents dynamically and access various functions with fewer button pushes. This remote control is equipped with a GPS function, temperature and acceleration sensors, a WLAN, and infrared and Bluetooth transmitters. It has a stylish design that will attract users while having all the hardware required to provide lifelog-based services. We will continue our research and development activities on remote applications for smartphones and other devices to create various lifelog-based services using the Coool remote control.

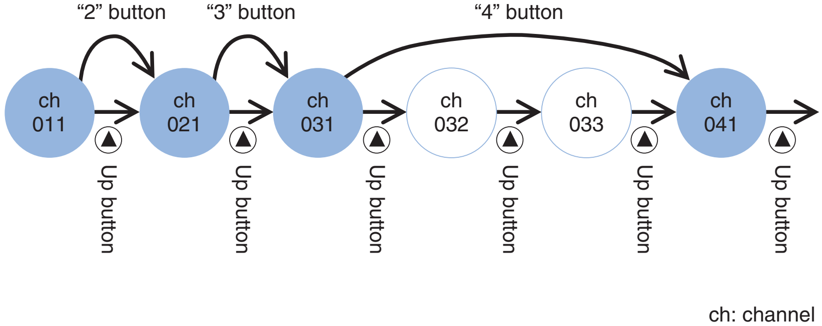
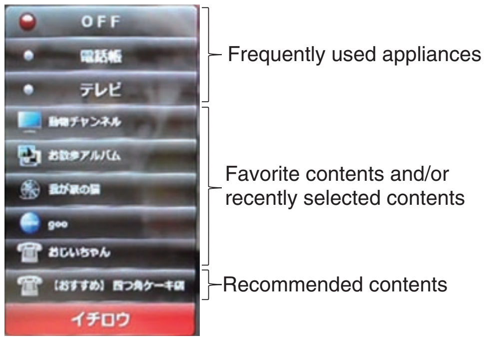


Fig. 4. Different TV status transitions corresponding to different buttons being pressed.

Fig. 5. Coool remote control for lifelog services.



* icons displayed on the left represent media.

Fig. 6. Example of My Menu.

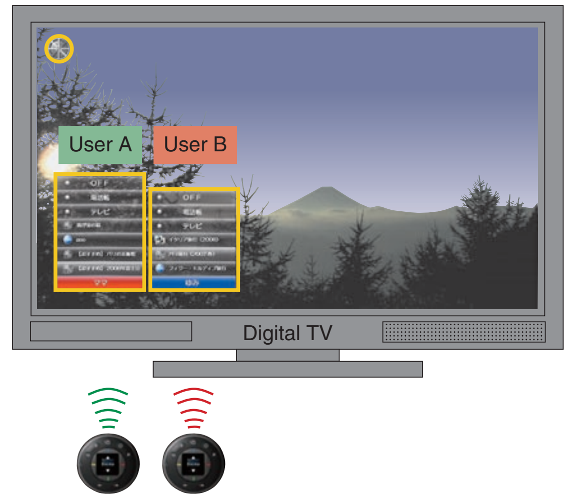


Fig. 7. Example of multiple My Menus displayed on one screen.

5.2 Contents menu for lifelog-based services

Users can display the contents menu on a TV screen. That makes it easier for users to select an appliance and issue detailed commands. As an example, My Menu sent by the Coool remote control is shown in **Fig. 6**. My Menu lists commonly accessed appliances and programs that the user likes and watched recently as well as contents recommended by lifelog-based services.

5.3 Simultaneous display of multiple My Menus

Each user has a different personal remote control, but multiple users can place their My Menus on the same screen at the same time (**Fig. 7**). Since My Menu may include information that a user does not want to share with others, the Coool remote control automatically alters the My Menu contents when another user is physically nearby.

6. Future plans

To create convenient and fun lifelog-based services, we will carry out feasibility studies of lifelog collection and device status estimation in actual home environments as well as validity tests of lifelog-based services as soon as possible.

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Data Stream Management Technology for Accumulating and Processing Lifelogs

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Abstract

In this article, we describe our data stream managing and processing technology, which accumulates and manages streaming log data sent from sensing devices and personal cellular phones and processes it nearly in real time. We also introduce the architecture of our Lifelog Management System (LLMS), which provides the technologies needed to support lifelog-based services.

1. Introduction

Services that offer attractive new functionalities through the use of various time-series data as lifelogs have been drawing attention. Such data includes time-series data generated from sensing devices, histories of personal activities collected from modern cellular phones, and log data accumulated in each information system. As shown in **Fig. 1**, users' location data collected by phones equipped with a GPS (global positioning system) function and users' context information such as their profiles and/or device operation histories can be accumulated. When all this data has been processed, users can be provided with personal recommendation services that suggest restaurants and tourist spots.

Such advanced services require the implementation of the following functions.

- Accumulation and management of enormous amounts of lifelog data collected over long periods of time on servers on the network
- Various types of processing in nearly real time taking into account the user's context
- Scalability for handling additional users and their requests
- Processing algorithm alteration or addition without service operation suspension

This article introduces our basic technology that helps to realize lifelog-based services.

2. Write-once read-many-times data management system

NTT Cyber Space Laboratories has been developing a write-once read-many-times data management system (DMS); it continually accumulates and manages time-series data, such as lifelog data, as a data stream and provides information to users after processing and integrating it. DMS can subject data streams to pre-registered processing algorithms every time new data arrives, so it can offer near-realtime event processing.

DMS can be run on clusters of personal computers (from one to a few hundred). It offers dynamic scalability of data processing (growth in scale) when information sources need to be added or the data volume increases. It also supports dynamic changes in processing algorithms (functionality enhancement) for data streams that arrive constantly. As shown in

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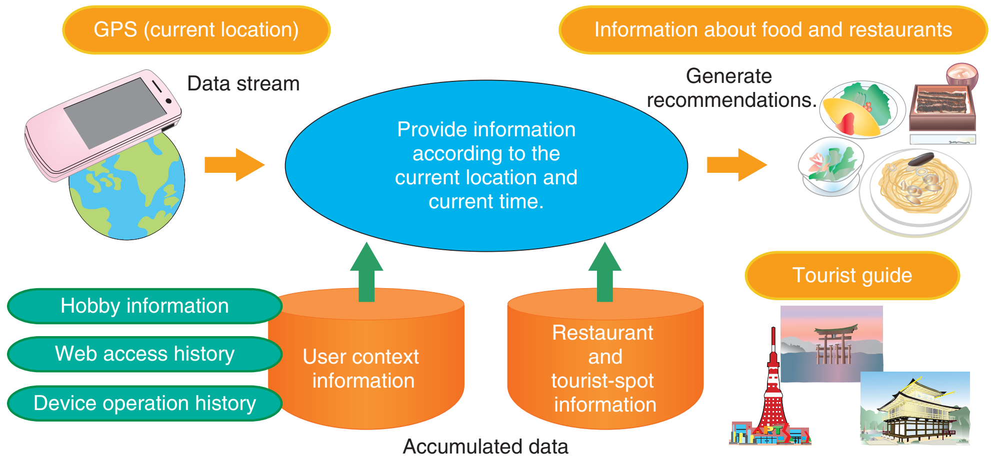

Fig. 1. Examples of lifelog services.

Fig. 2, DMS has a three-layer architecture consisting of queues, which receive and accumulate data; filters, which process received data and integrate accumulated data; and views, which provide processing results for each application.

(1) Queues

Each information source is associated with a different queue. Each queue receives and accumulates a data stream generated from the information source via *add client*. A new information source can be supported by adding a new queue.

(2) Filters

Filters pull data from queues, apply the processing algorithms set for each information source to the data, and send the processing results to views. Each filter determines which queue it should get data from on the basis of the data arrival rate. If the data volume and number of processing operations increases, the

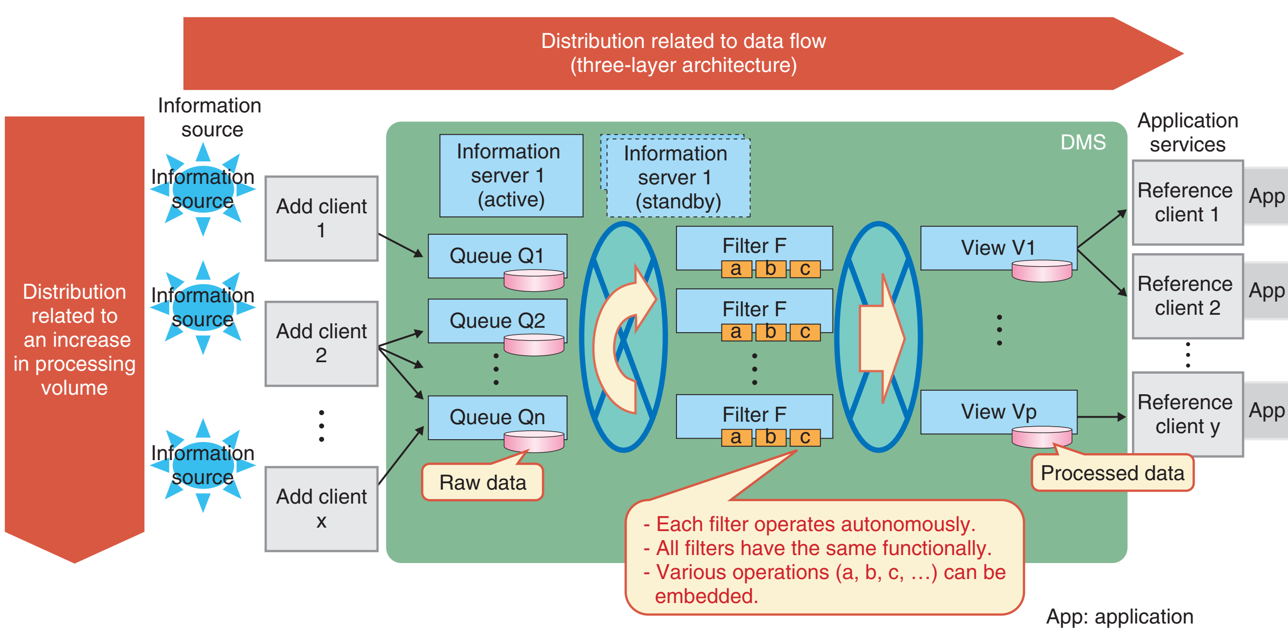

Fig. 2. Architecture of write-once read-many-times DMS.

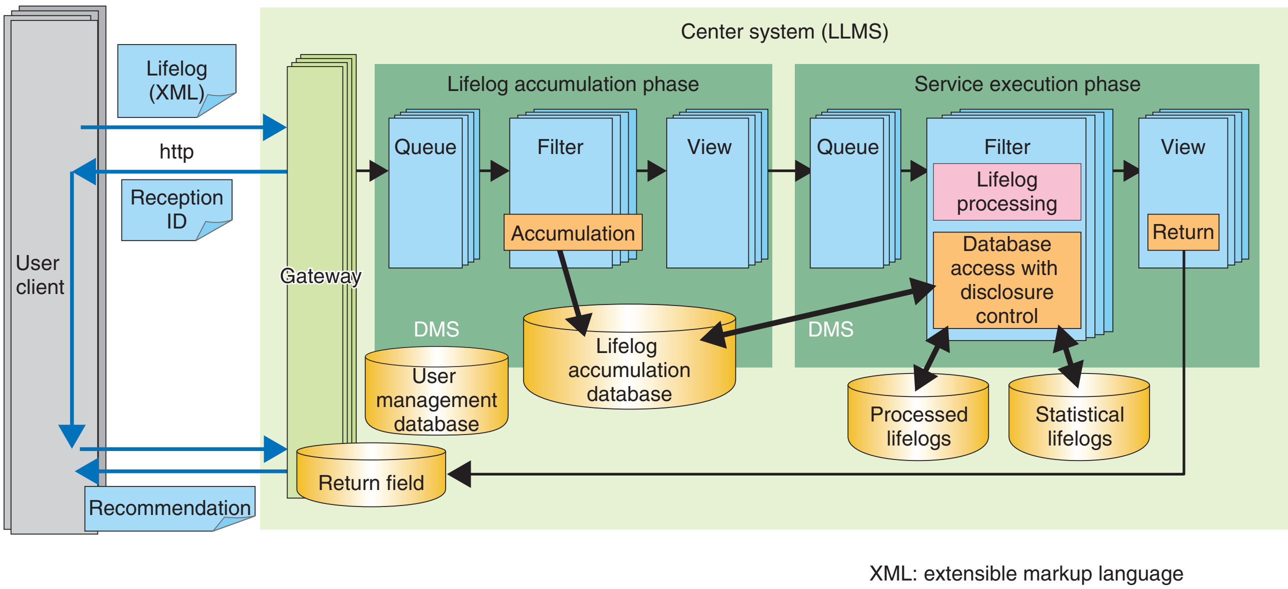

Fig. 3. LLMS structure.

processing throughput can be improved by setting additional filters, without suspending operations (growth in scale). Furthermore, processing algorithms can be changed and new algorithms can be added before the next data is obtained from queues (functionality enhancement).

(3) Views

Views integrate the results yielded by the filters to offer integrated results for application services. The integrated results can be accumulated in a database or sent to another server by HTTP (hypertext transfer protocol) calls.

3. Lifelog Management System

The Lifelog Management System (LLMS) utilizes the characteristics of DMS. As **Fig. 3** shows, LLMS consists of a two-layered DMS and the lifelog database. The first layer of DMS, the lifelog accumulation phase, receives individual lifelogs from users' clients and stores them in the lifelog database. The second layer, the service execution phase, accesses the data in the lifelog database, executes the operations registered for each service, and outputs the results to the return field. Processing throughput can be improved to match an increase in the number of users by adding filters in the first layer and utilizing the growth-in-scale feature of DMS. Moreover, it can be improved to handle any increase in the number of services by adding filters in the second layer.

3.1. Workflow of LLMS

1) Each user sends lifelog data to the center system via the user's client and requests the execution of desired lifelog-based services.
2) The center system issues and returns a reception identifier (ID) to each request from a user client.
3) The user client acquires the service results from the return field, which can be accessed only by using the reception ID as the key.

Since services are executed asynchronously with respect to user requests, the user can get execution results whenever desired even if they take a long time to generate.

3.2. Lifelog accumulation database

The lifelog data sent from each user is stored in the database in the first layer of DMS, the lifelog accumulation phase. We believe that lifelog data must be handled in a unified manner under the assumption that this database will need to accumulate a large number and variety of lifelogs, such as GPS-generated user location information, names of products users bought and shops where they bought them, users' website access histories, and metadata of pictures taken by the users. Moreover, in the near future,

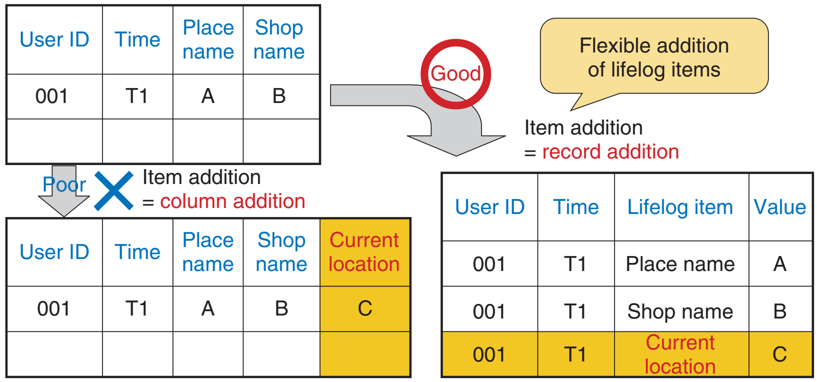

Fig. 4. Addition of new lifelog items.

many other sorts of lifelogs will emerge with the emergence of novel sensor devices and/or new services.

As just described, the lifelog database must be flexible to adapt those various lifelogs in an integrated manner and its table structure must be flexible in order to add new lifelog items easily. Thus, for our database we chose to use the idea of a *key-value store*. For example, as shown in **Fig. 4**, when the new lifelog item *current location* is added, it is handled not as a column addition to an existing table but as a *record addition*, so the table structure of the lifelog database does not need to be changed during processing.

3.3. Lifelog addition, updating, and erasure

Lifelogs received from users will be stored as log data in the lifelog database. Those newly stored lifelogs are basically used only for viewing. However, to provide flexibility in supporting requests to update or delete stored lifelog data, the lifelog database has *update time* and *erase flag* items as system management information, in addition to the lifelogs received from users. Examples of adding data to a lifelog, updating a lifelog value, and erasing a lifelog are shown in **Fig. 5**.

When new data needs to be added (Fig. 5(a)), the update time is set to the time at which the data was added (T2) and the erase flag is set to false.

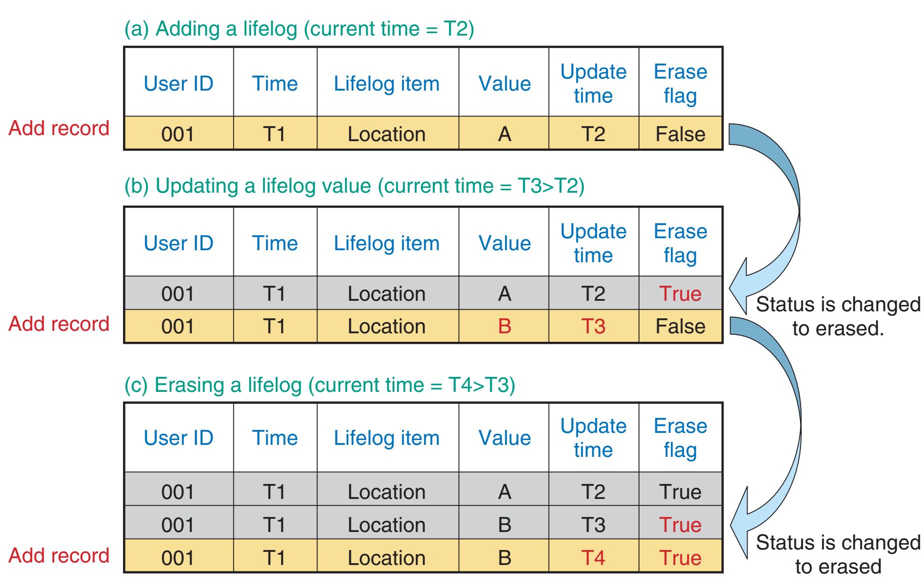

Fig. 5. Lifelog addition, updating, and erasure.

When a lifelog value needs to be updated (Fig. 5(b)), the record data whose update time is T2 is logically deleted by changing the erase flag from false to true (row 1). Then, a new record whose lifelog item value is B (instead of the previous value of A), update time is T3, and erase flag is false is added (row 2).

When a lifelog needs to be erased (Fig. 5(c)), the data's erase flag is changed from false to true to erase the data logically (row 2), in a similar way to Fig. 5(b). Furthermore, a new record whose update time is T4 and erase flag is true is added (row 3).

As you can see, the update time can be used to create a history of when lifelog records were added, updated, or erased. Moreover, the logically erased state achieved by using the erase flag enables lifelog updating and erasure to be supported while the lifelog-operation history itself is being recorded as a lifelog.

4. Conclusion

We are currently conducting field experiments on restaurant recommendations based on user context information as one example of a lifelog-utilizing service provided from modern cellular phones with a GPS function. We will strive to develop new technologies to support extremely large-scale services while continuing the field experiments and we will continue to research and develop the basic technology needed for new lifelog-based services.

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Social Science Research Approach for Lifelog Utilization

Katsumi Takahashi†

Abstract

This article describes privacy issues related to the use of lifelogs. After mentioning legal systems for privacy, it introduces privacy preserving data utilization technologies. It also describes research trends for major techniques such as data anonymization and secure function evaluation. Some important aspects of lifelog utilization are cooperation among service design, legal system preparation, and privacy preserving data utilization technologies.

1. Introduction

Can lifelogs be used to improve services? My colleagues and I believe that lifelogs are useful in several daily situations. For example, you may have experienced getting a good book recommendation from an online bookstore and some people would be interested in pedometer records on their mobile phones to monitor their health. These services can be provided automatically by collecting and analyzing records of actions, which are called lifelogs. The mechanism is based on the concept that collecting more action records enables more useful information to be found in them. This mechanism requires precise action records from other people. However, if we collect more action information, privacy issues arise. We should avoid collecting action information that is identified with specific people because that would represent a breach of their privacy. We are the first generation whose lifelogs are being collected and utilized. Nobody knows the proper way to use lifelogs yet.

Who can answer the question of how to use lifelogs properly? First, the end users who provide the lifelogs must give consent. Second, service or business model issues that provide merits for both users and service providers should be discussed. Third, continuing lifelog utilization requires legal systems to show the standard or adjust interests. Such discussions have led to the development of some technologies, which are collectively called privacy preserving data utilization (PPDU) technologies. Establishing lifelog-based services requires a cooperative approach among useful services, legal systems, and PPDU technologies (**Fig. 1**).

NTT Information Sharing Platform Laboratories is interested in personal data utilization technologies and is discussing the issue of technologies and social systems. This article describes trends of legal systems and PPDU technologies.

2. Legal systems for lifelogs

In Japan, there are currently no laws or guidelines directly related to the use of lifelogs. We must determine the basic idea from the traditional privacy protection scheme. OECD (Organization for Economic Cooperation and Development) published "OECD Guidelines on the Protection of Privacy and Transborder Flows of Personal Data" in 1980. It recommends the way to handle personal data including, collection limitation and purpose specification principles. These recommendations have become the basis for the personal data processing of each country, including Japan.

OECD's recommendations are shown in **Fig. 2**. The "Act on the Protection of Personal Information" (Act on PPI) was worked out in 2003. In this law, personal information is defined as shown in **Fig. 3**. "Proper

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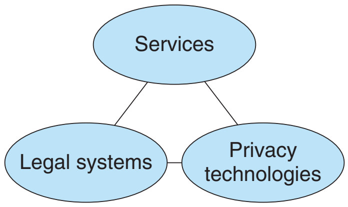

Fig. 1. Triangle for lifelog utilization.

1. Collection Limitation Principle
2. Data Quality Principle
3. Purpose Specification Principle
4. Use Limitation Principle
5. Security Safeguards Principle
6. Openness Principle
7. Individual Participation Principle
8. Accountability Principle

Fig. 2. OECD's privacy principles.

Article 1 Definitions

The term "personal information" as used in this Act shall mean information about a living individual which can identify the specific individual by name, date of birth or other description contained in such information (including such information as will allow easy reference to other information and will thereby enable the identification of the specific individual).

Fig. 3. Definition of personal information.

acquisition" (Article 17), "Notice of the Purpose of Utilization" (Article 18), and "Restriction of Provision to a Third Party" (Article 23) are defined.

This law has clarified what should be observed when handling personal information. Lifelog handling is often regarded as personal information handling, but there is discussion that the Act on PPI does not help lifelog utilization although "consideration of the usefulness of personal information" is described in the purpose chapter (Article 1). The discussion includes "Does the Act on PPI catch up with new market needs or social needs?" and "what kind of lifelog corresponds to personal information?"

The "Information Grand Voyage" project of the Ministry of Economy, Trade and Industry (METI) from 2007 to 2009 investigated personal data utilization. The main technological idea for safety is the anonymization of identifiable personal information. A study for best practices has been conducted and the software platform for anonymization has been developed [1]. A Ministry of Internal Affairs and Communications (MIC) study group that has been discussing issues related to information and communications technology (ICT) services from the user's standpoint since 2009 has reviewed lifelog services and made some proposals. The proposal documents request the following: "A lifelog is a broad notion that includes web access histories, payment histories, and location histories. Although information for targeted advertisements does not require personal identifiable information, if it can be identified by looking up other data, or inferred from data collected over a long term, it should be regarded as personal information." [2].

Considering social trends and needs, the approaches of both METI and MIC encourage the drawing up of independent guidelines rather than the designing of controlling institutions. We believe that any approach requires operations that use privacy protection technologies.

3. Privacy preserving data utilization

In developing services that use lifelogs, one must take care to ensure the privacy of the persons providing the lifelogs. In the same way that the balance of a bank account is shared only by the account holder and the bank, if a lifelog is shared only by the system and used for the person, the usual security control works well. But lifelogs may be shared by several systems, so privacy is important. A framework of lifelog processing is shown in **Fig. 4**. First, the raw lifelog provided by a certain person should be collected ((a) in Fig. 4). Second, there are issues concerning the processing of collected lifelogs, such as storing and analyzing them (b). Third, after analysis, the analyzed statistical data might require privacy (c). PPDU is a technique that preserves privacy throughout these steps.

PPDU covers three methods [3] (**Fig. 5**). In this article, we describe the classic data anonymization

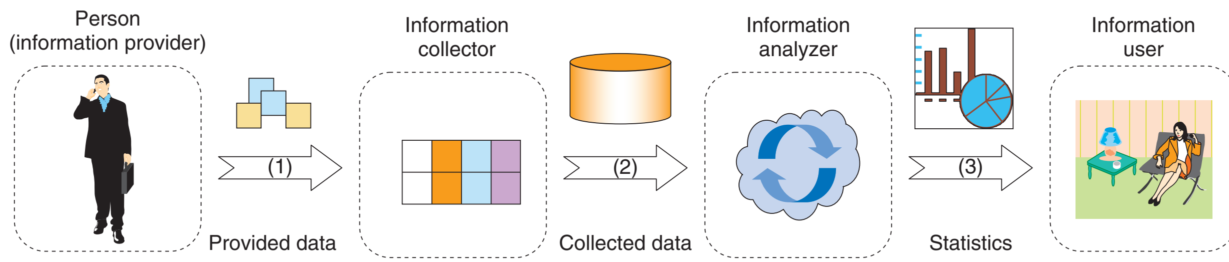

Fig. 4. Lifelog handling process.

Anonymization: Generalizing data so that it cannot be identified (example) Ginza, Chuo, Tokyo; male; 33 → Chuo, Tokyo; male; 30s
Perturbation: Adding noise to generate perturbated pseudo data (example) Ginza, Chuo, Tokyo; male; 33 → Ginza, Chuo, Osaka; male; 35
Secure function evaluation: Analyzes encrypted data without revealing the raw data (example) Ginza, Chuo, Tokyo; male; 33 → %52TE4AS &HR*YS S!A@3S

Fig. 5. Three types of PPDU.

and the development of an improved secure function evaluation.

4. Data anonymization

If you wish to share a large amount of personal data (such as lifelogs), anonymization, it is a good idea to make data unidentifiable. The basic method for doing this is anonymization, which is a method of modifying the data to make it unidentifiable while leaving as much useful information as possible. There is an empirical method of suppressing identifiers such as names and addresses. However, even if names and addresses are deleted from the data, some data could be identified if it contains unique hobbies or actions. Such data is not safe in terms of privacy. On the other hand, if you generalize the data too much in consideration of privacy, the data will be less useful. What is required is an anonymizing method that controls data for both safety and utility. A data anonymization technology and a method for efficiently dealing with this trade-off have been studied.

One major measure is k-anonymity. This represents the data status that there are at least k records that share the same combination of attributes (which might be used for identification, such as post code, sex, and age, as shown in **Fig. 6**). Anonymization software that produces k-anonymized data efficiently has been developed in the Information Grand Voyage project.

5. Secure function evaluation

Another method for processing more sensitive data is called secure function evaluation (SFE). This technique analyzes the data under a prior agreement without revealing the raw data to anyone involved in the whole process. Ordinary cryptographic techniques must decrypt encrypted data in order to analyze it. But NTT's SFE, which we have been developing, divides the original data into several fragments, processes the data fragments, and restores only the calculated result to a visible format.

A simple example of SFE is shown in **Fig. 7**. It shows the process of calculating the average score of three children without revealing their raw scores to anybody else. First, each student splits his or her score into two parts and sends each part to a different server. The two servers calculate the average of all the fragments they receive and these two average scores can output the average score of the three children. SFE can provide not only this elementary sum function, but also four arithmetic operations and logical operations including accordance and numerical comparison. By combining these operations, SFE can perform complex processes such as providing statistics, data matching, and data mining. SFE requires two or more individual computing agents, as

Collected data

No.	Name	Post code	Sex	Age	Hobby
1	Alice Cooper	1800005	Male	38	Animation
2	Bob Dylan	1800012	Male	39	Animation

Suppression

Anonymized data

No.	Name	Post code	Sex	Age	Hobby
1	Suppressed	1800005	Male	38	Animation
2		1800012	Male	39	Animation
3		1800003	Male	37	Animation
4		1810015	Female	40	Movie
5		1810015	Female	46	Animation
6		1810013	Female	43	Drama

k-anonymization

k-anonymized data

No.	Post code	Sex	Age	Hobby	
1	18000**	Male	30s	Animation	3
2	18000**	Male	30s	Animation	
3	18000**	Male	30s	Animation	
4	18100**	Female	40s	Movie	3
5	18100**	Female	40s	Animation	
6	18100**	Female	40s	Drama	

Generalized

Fig. 6. Example of k-anonymization (k=3).

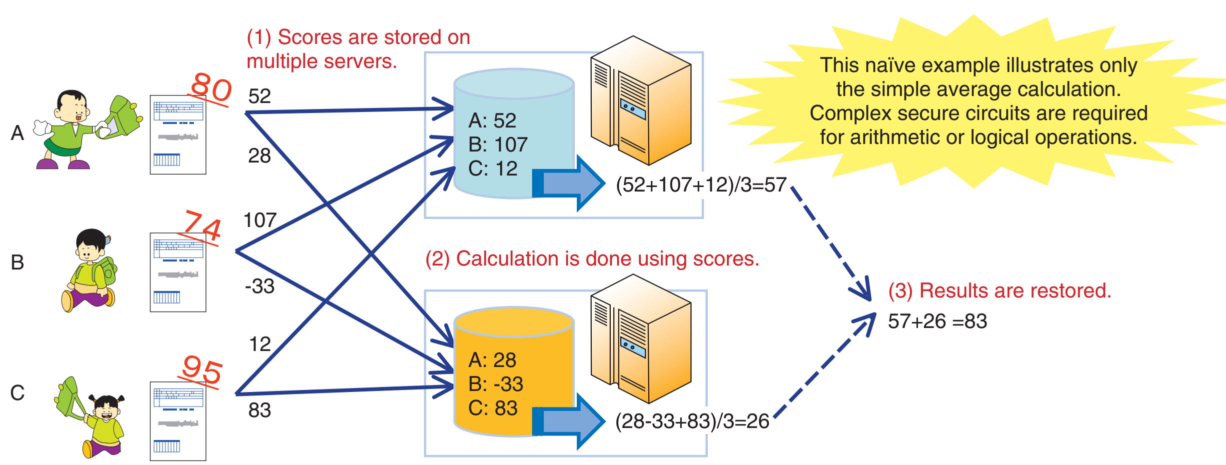

Fig. 7. Simple example of average score calculation using SFE.

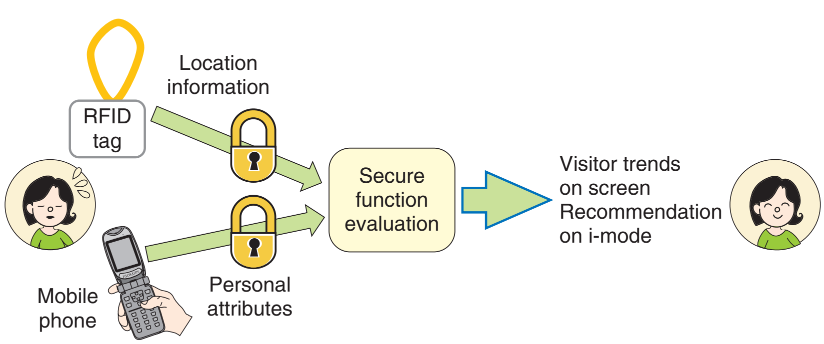

Fig. 8. SFE demonstration experiment.

shown in Fig. 7, as the basis of data protection. For the processing of sensitive data like lifelogs, a technique like SFE is needed and a cloud service that deploys such secure functions is desirable. To date, SFE has been generally believed to be impractical because of its slowness, but NTT's SFE has demonstrated the ability to calculate the maximal value of 1000 data items within one second, which proves its practicality.

6. SFE demonstration experiment

NTT Information Sharing Platform Laboratories conducted an SFE demonstration experiment at NTT R&D Forum in February 2010 (**Fig. 8**). In this experiment, we succeeded in analyzing the location information of forum participants while keeping personal information secret. 1000 visitors wore radio-frequency identification (RFID) tags to record their locations. In addition, they registered their personal attributes, such as affiliations and occupations, from personal computers or mobile phones. The collected information was analyzed safely using NTT's SFE to show the trend of visitors to each exhibition and to recommend exhibits for each visitor [4].

7. Conclusion

This article mentioned legal issues for lifelog utilization, introduced privacy preserving data utilization (PPDU) technologies, and described research and development in NTT Laboratories. We are working hard to make PPDU practical and to provide a platform for sharing lifelogs safely with assured privacy.

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Restaurant Recommendation Service Using Lifelogs

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Abstract

This article introduces a service that presents information about restaurants according to time, place, and occasion by using user preferences and behavior history. To make this service a reality, we have developed a variety of technologies, including technology for automatically obtaining user preferences from a record of terminal operations, GPS-based technology for automatically determining who, if anyone, is accompanying the user, and technology for automatically predicting the user's destination from his or her behavior history (GPS: global positioning system). We describe the construction of a restaurant recommendation system for smartphones equipped with these lifelog processing technologies and present the results of field experiments targeting general users.

1. Existing restaurant recommendation services

Services that search for and recommend restaurants are quite popular on websites designed for access from desktop computers and mobile devices. A typical function of these services is to present a list of restaurants that match information input by the user such as desired district and type of cuisine. Some services can even display restaurants near the user's present location provided that the user's terminal is equipped with a GPS (global positioning system) function.

2. Advanced restaurant recommendations using lifelogs

NTT Cyber Solutions Laboratories aims to create advanced restaurant recommendations that suit the user's condition by using personal lifelogs. Specific examples of target services are given below.

(1) Determining the user's food preferences and recommending restaurants starting with those most likely to satisfy the user (**Fig. 1**)

(2) Determining whether the user is alone or with other people and recommending restaurants that should satisfy everyone (Fig. 1)

(3) Inferring where the user may go next and recommending restaurants near that location ahead of time in addition to restaurants near the present location (**Fig. 2**)

In developing these services, we targeted users having GPS-equipped smartphones.

3. System configuration

The configuration of the entire system is shown in **Fig. 3**. To begin with, we selected an Android terminal as the type of handset to be carried around by the user owing to its ease of operation, ease of viewing, and ease of development for a restaurant-recommendation service. In addition to listing restaurant information, this type of terminal can also maintain logs of GPS coordinates, azimuth data, and acceleration values and can keep a history of terminal operations.

A terminal operation history consists of, for example, detailed screens describing restaurants that are acquired whenever the user views them. This data is

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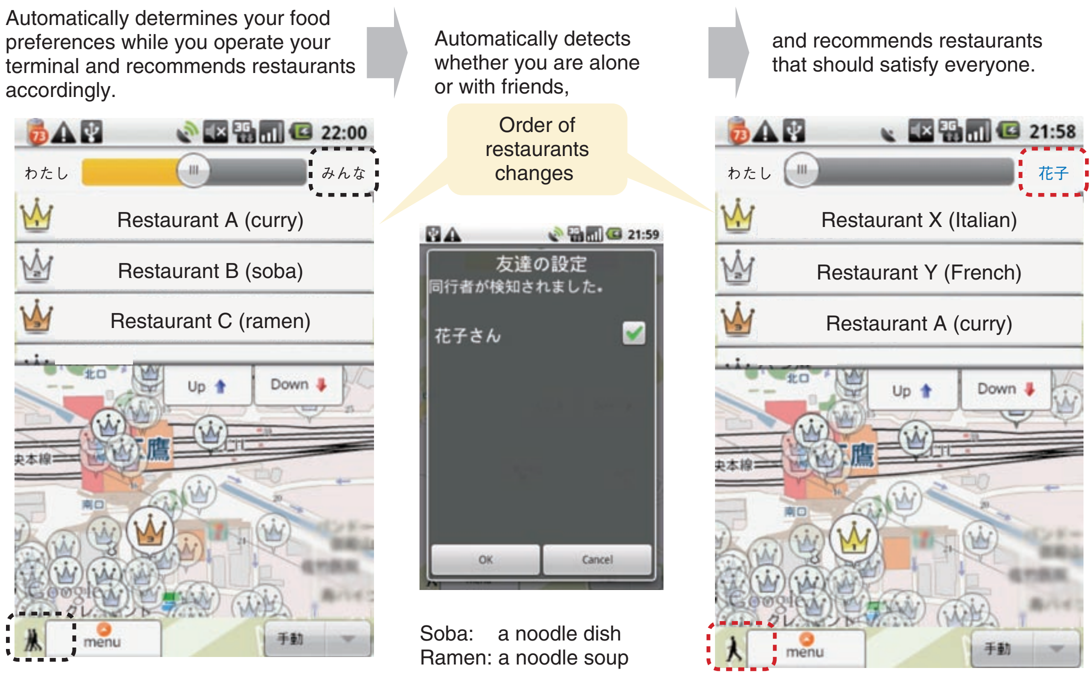

Fig. 1. Overlay of restaurants according to user or group preferences.

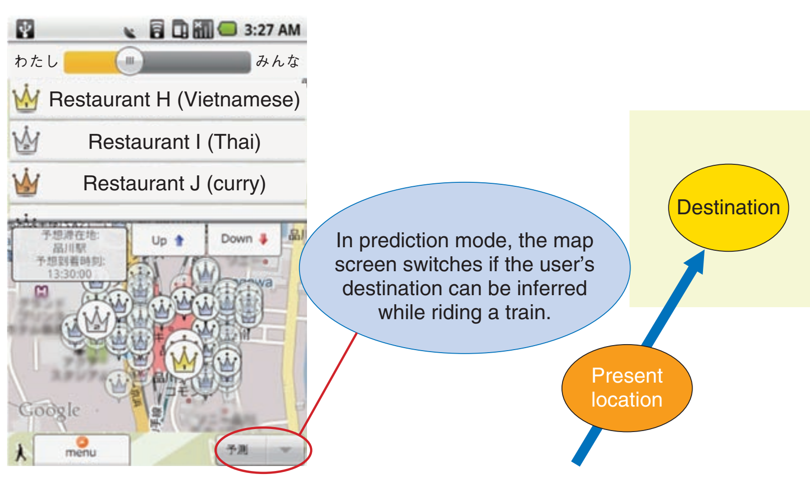

Fig. 2. Destination prediction.

sent to the user profile server, which processes it as a log of terminal operations to gauge user preferences. At the same time, GPS data is gathered regularly from every few seconds to every few minutes and sent to the Lifelog Management System (LLMS), which uses the terminal operation history log to perform the following types of processing: determine means of transport, extract the present location, determine if the user is alone or with friends, extract movement patterns, predict the destination, and determine whether today is a routine or non-routine day.

The user profile server also has a function for using the lifelogs generated by the above processing to search for restaurants that suit the user's condition and send a list of those restaurants to the terminal.

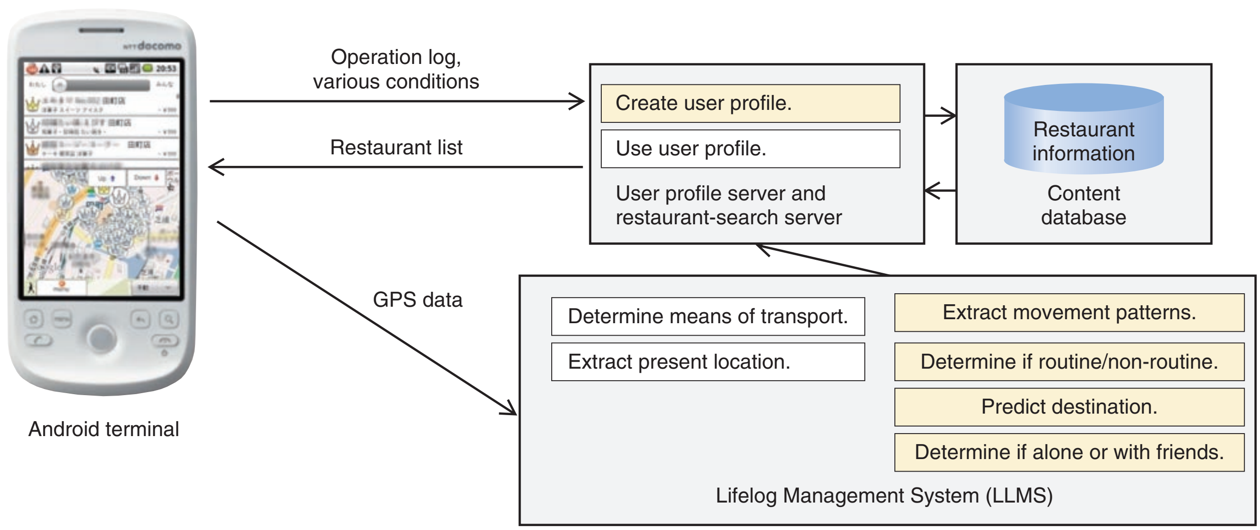

Fig. 3. System configuration and lifelog generation processing.

4. Lifelog generation functions

The lifelogs generated by this system are summarized below.

(1) User preferences

This system uses a conceptual structure of the target domain to determine user preferences. In the example in **Fig. 4**, *tonkatsu* (pork cutlet) is categorized as a type of meat dish, a type of Japanese food, and a type of fried food. Let's say that the user has at one time selected tonkatsu. It would be impossible to determine which type of Japanese food, meat dishes, or fried food the user likes best if this is the only food-selection history to go on. In time, however, as more food selections are added to the user's history, it should be possible to say, for example, that the user prefers Japanese food over meat dishes and fried food. Here, to prevent the system from becoming stuck on certain preferences or to counter erroneous learning, a mechanism that forgets learned preferences to some extent has been incorporated.

The learning of preferences in this system is performed by time period. In this way, preferences that correspond to particular times of the day, such as "Japanese-food/ramen for lunch" and "Japanese pub in the evening", can be learned (ramen: a noodle soup). By learning preferences, we can generate a preference model for the user. And this system can combine the preferences of multiple users.

(2) Alone or with friends

Determining whether the user is alone or in the company of friends on the basis of their GPS data can be difficult if the accuracy of longitude and latitude data is poor owing to, for example, the presence of a high-rise building in the vicinity. To deal with this problem, we define a new index using reliability information accompanying GPS data and, as a result, achieve a high rate of correct results compared with determining the presence of friends using only longitude and latitude data (**Fig. 5**).

(3) Feature movement patterns

Characteristic behavior patterns for each user can be uncovered by obtaining GPS data over a relatively long period (about one week) (**Fig. 6**). This system first extracts a history of where the user stays (addresses) based on a log of GPS data and then uses sequential pattern mining and threshold processing to extract feature movement patterns.

(4) Destination prediction

The next place (destination) that a user will be going can be inferred by matching up movement patterns and present location and time (Fig. 6). In these experiments, we achieved a function for recommending restaurants not only near the user's present location but also near the user's destination.

(5) Routine/non-routine day

When predicting destination, it is clear that high

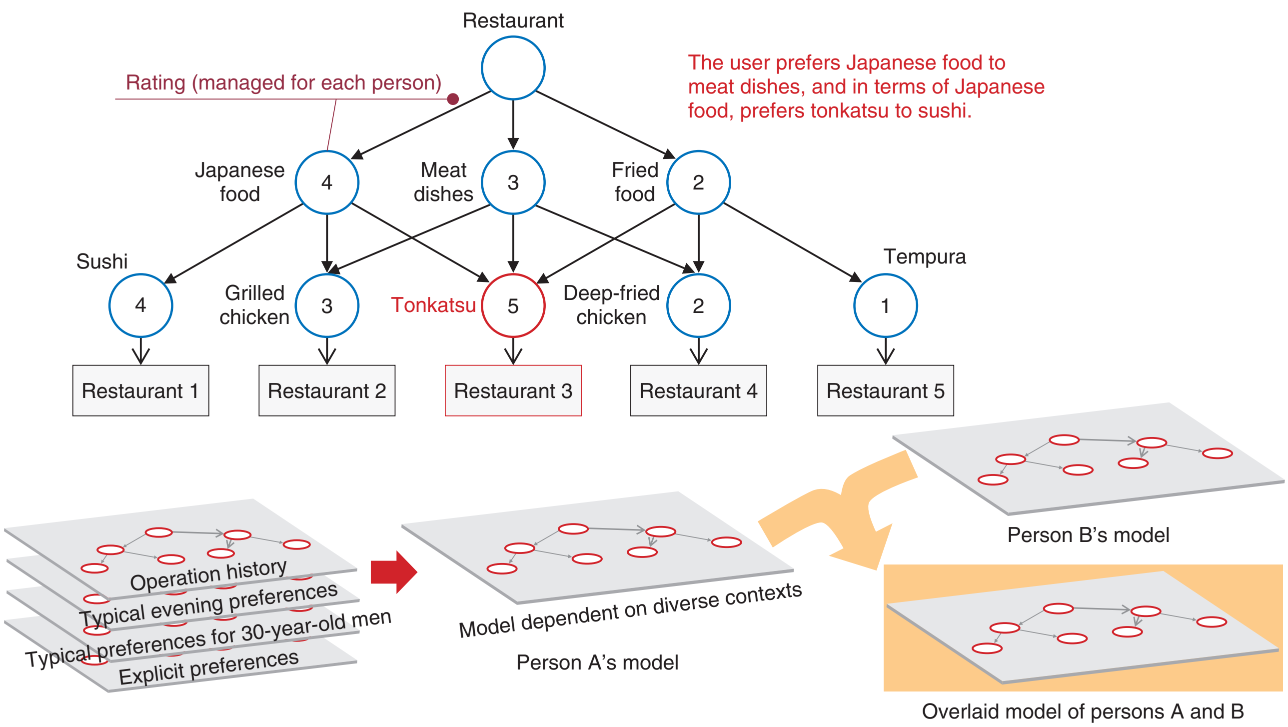

Fig. 4. Determining user preferences.

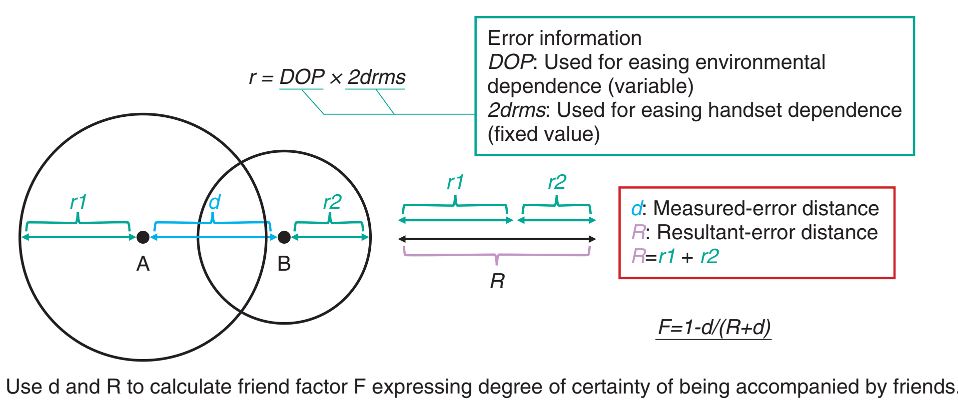

Fig. 5. Determining if alone or with friends from GPS data.

accuracy cannot be obtained if the user is currently at an irregular location. For this reason, we have incorporated processing for automatically determining whether the day on which the user's destination is being predicted is a routine day (regular pattern) or non-routine day. This processing makes use of the user's history of visited places and a support vector machine (SVM) (**Fig. 7**).

5. Field experiments

To test this system, we conducted field experiments targeting general users in August and September 2009 (1st trial) and February 2010 (2nd trial) together with NTT Communications and NTT Resonant. We passed out Android terminals to 50 subjects in the 1st trial and about a dozen subjects in the 2nd trial. In both trials, the subjects belonged to nine categories

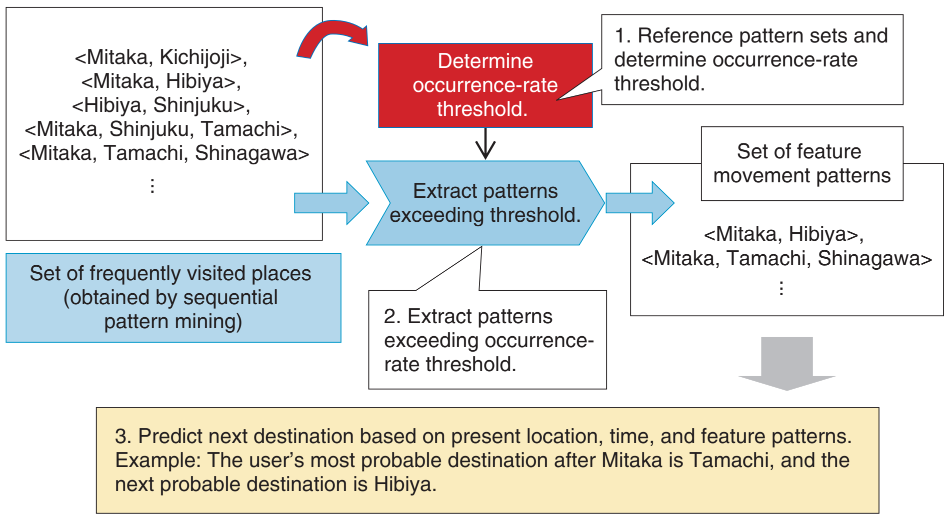

Fig. 6. Extracting feature movement patterns and predicting destination.

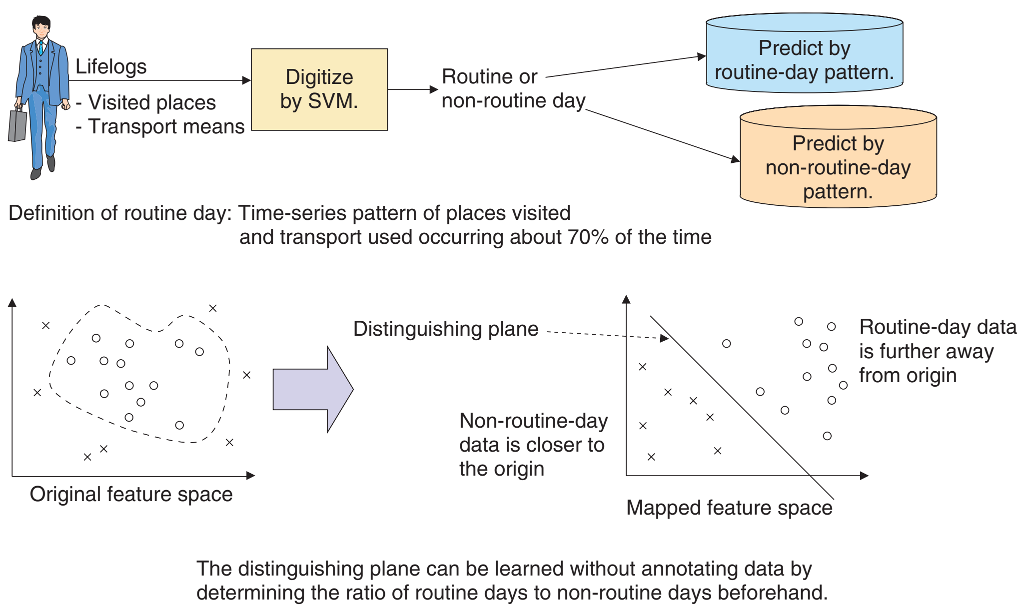

Fig. 7. Determining routine or non-routine day.

(students, sales workers, food connoisseurs, etc.) and they used this recommendation service for about a month.

Comments received by a questionnaire-based survey and interviews conducted after the experiments revealed that more than 90% of users wanted to continue using the service and that more than 60% felt that the service is superior and more useful than existing restaurant recommendation services. On the other hand, it was also said that the results of user preference determination and destination prediction could be more accurate. In particular, we found that a user's preferences could be swayed by mood, current situation, and other factors and that there was a need to determine the user's state in more detail when recommending restaurants.

6. Future plans

Using the results of the abovementioned two field experiments, we plan to continue our research and development efforts with the aim of achieving an engine that can obtain a deeper understanding of the user by improving the accuracy of lifelog generation techniques and increasing the variety of lifelogs.

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Prospects for Using Lifelogs in the Medical Field

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Abstract

In this article, we introduce studies being conducted in cooperation with Kyoto University Hospital in relation to new medical and healthcare services that make use of various lifelogs in every-day life as well as medical information obtained within medical facilities.

1. Introduction

In the medical field, it is necessary to gather as much personal information as possible about patients in order to achieve high-quality diagnosis and treatment. Until now, the personal information used in diagnosis and treatment has basically been gathered and used only within medical facilities. It consists of clinical records, test results, medical images, and other such information. However, the medical information that can be gathered within a medical facility is very limited. It would seem that there is a large amount of data that would be useful for medical purposes within the voluminous and varied data gathered in daily life, most of which is spent outside medical facilities, but such lifelog data has gone unused in most cases.

2. Use of lifelogs for medical diagnosis and treatment

Since June 2009, we have been conducting various studies in cooperation with the Kyoto University Hospital to assess the possibilities for using such lifelog data, obtained outside medical facilities, for medical purposes. In this article, we introduce two such studies. The first aimed to evaluate how vital data obtained outside medical facilities (weight, blood pressure, number of steps walked, etc.) can be useful in medicine. The second concerned the development of technologies that can automatically gather a variety of lifelog data without placing undue burden on the user.

2.1. Experiments linking medical information and lifelogs

In these experiments, the Maiko-Net Web service, which is operated by Kyoto Association for Cooperative Medicine (a non-profit organization) with participation from the Kyoto University Hospital, was used as a platform for accumulating medical information within a medical facility. Maiko-Net is a regional medical infrastructure service linked to medical facilities in Kyoto prefecture, with functions for sharing medical information among medical facilities and allowing the public (patients receiving treatment at a medical facility) to view some of this information. For example, a Maiko-Net user receiving treatment at Kyoto University Hospital can view the results of all past blood tests (cholesterol levels, etc.) at any time. For these experiments, Maiko-Net was linked to "goo Karada Log" (*karada* is the Japanese word for body), which is a lifelog service on the goo Web portal oriented to the health field provided by NTT Resonant Inc. This created a mechanism allowing healthcare practitioners and the general public to access medical information gathered in medical facilities and lifelog information gathered outside medical facilities in an easy and secure manner (**Fig. 1**).

In mid-December 2009, an announcement was issued to Maiko-Net users receiving treatment at

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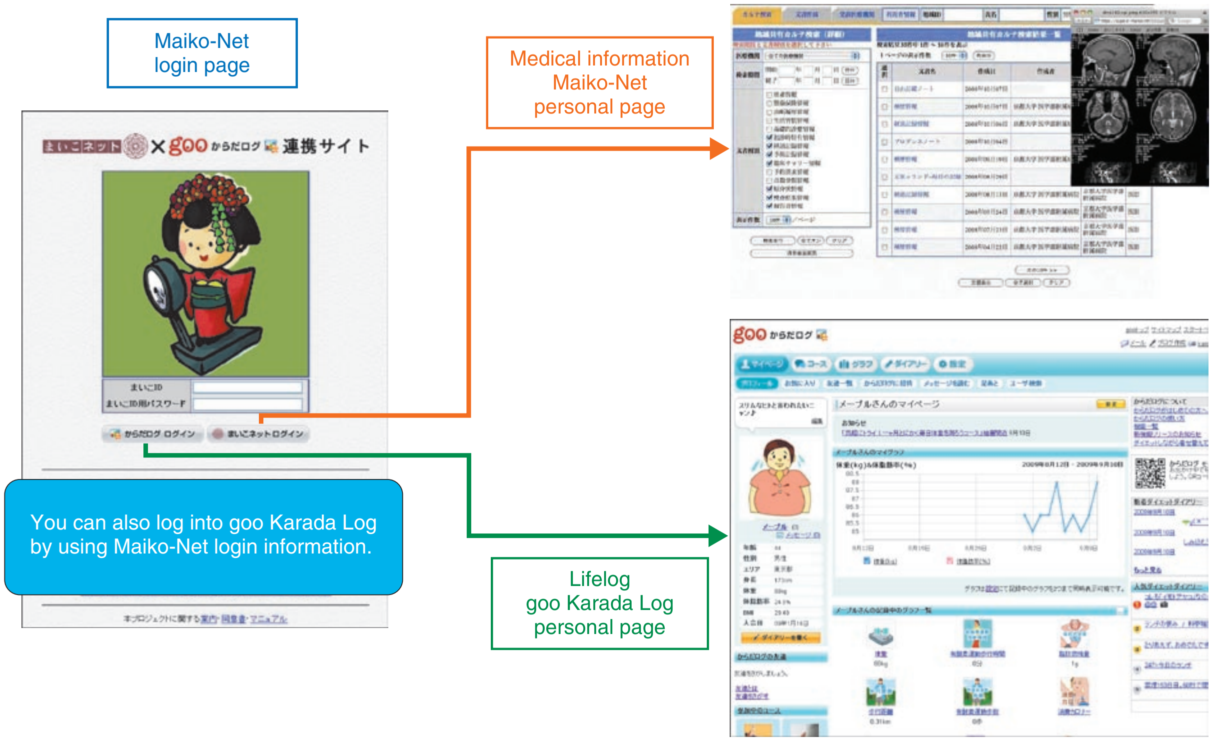


Fig. 1. Test system.

Kyoto University Hospital in order to recruit participants for experiments. Over several months beginning at the end of December, the recruited participants recorded lifelogs on goo Karada Log using the new mechanism. They were recommended to record a set of lifelog data consisting of about 30 items such as blood pressure. These items were selected as being correlated to lifestyle diseases, such as diabetes and high blood pressure, which occur frequently in the Maiko-Net membership, on the basis of advice from doctors at Kyoto University Hospital. Participant login information for Maiko-Net was also linked to goo Karada Log for the convenience of participants, so that logging into the Maiko-Net personal page also provided seamless login to the goo Karada Log personal page.

At the end of February 2009, we conducted a survey of participants and we had a meeting with doctors at Kyoto University Hospital to evaluate the potential for using lifelogs for medical treatment. The following is a summary of the responses to the participant survey.

(1) Approximately half of the participants were already recording health information daily before these experiments began (although for most of them this consisted of handwritten records). Moreover, most of the health information they were recording was covered by the lifelog items recommended for these experiments.

(2) In the experiments, almost 20% of the participants recorded health information every day using the constructed system.

(3) Almost all of the participants wanted healthcare practitioners to view the lifelog data.

The main comments received in the meeting with medical doctors were as follows.

(1) They were not particularly concerned that the lifelog information gathered outside medical facilities might be too inaccurate.

(2) Measurements such as body weight and blood pressure fluctuate depending on when they are taken, so lifelog data gathered over several days rather than the single measurements taken during out-patient treatment allows trends to be understood, and this is important.

(3) In addition to numerical lifelog data, free comments such as “felt dizzy” are important.

(4) It would be better if average, abnormal, and target values for each lifelog item could be

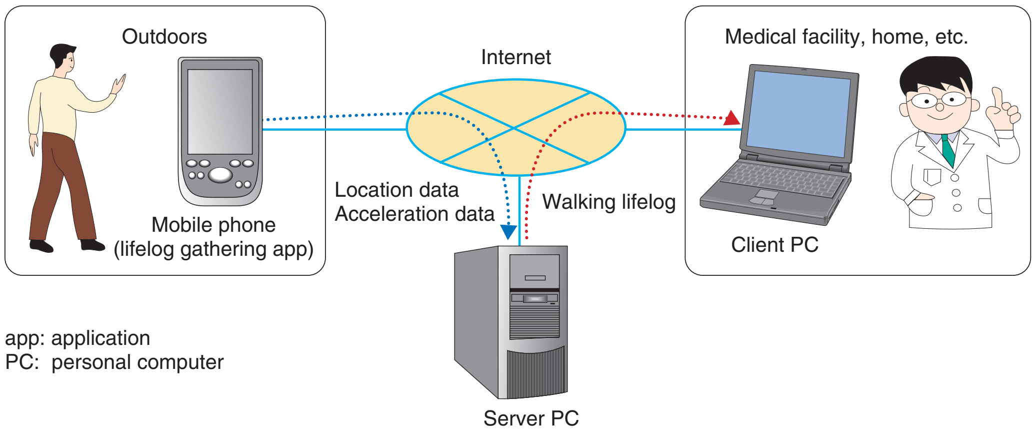


Fig. 2. System diagram.

displayed to patients.

Using the above results as a starting point, we will continue to study ways of making lifelog recording easier for patients and also study methods of linking lifelog services to medical data systems in medical facilities, so that patient lifelogs can be viewed and used easily by medical practitioners.

2.2. Gait visualization technology

In rehabilitation and the treatment of lifestyle diseases, it is important to record conditions and activity related to walking. Medical facilities have large on-site analytical equipment that can record gait in detail, and this has been useful for treatment. However, information recorded in a medical facility in this way is extremely limited in time and space, so a way of recording walking behavior under normal conditions is desirable for rehabilitation and other types of treatment. With this in mind, we have developed technology for visualizing lifelog data related to walking in ordinary life. It records when, where, and in what manner a person walks.

In developing this technology, one of our goals is to minimize the load on the user by only requiring the user to carry the data-collection terminal. In gathering continuous lifelog data, it is very important not to require much effort from the user. Considering the proliferation of mobile phones with sophisticated functions such as GPS (global positioning system) and accelerometers and the fact that it is fairly common for people to carry a mobile phone, we decided to use a mobile phone with these functions as the data collection terminal.

This technology has two main features. The first applies signal processing to the acceleration signals to distinguish periods of walking and identify details of the gait. In daily life, we perform various actions, such as resting or riding a train or bus, in addition to walking. To record a representation of this in daily life, the system constantly records acceleration signals, and walking periods are identified by finding segments within these signals that have characteristics that indicate walking. The system can also analyze and display the walking segments in further detail, for aspects like the pace of walking and shifts in balance. This provides a clearer view of what type of walking is occurring.

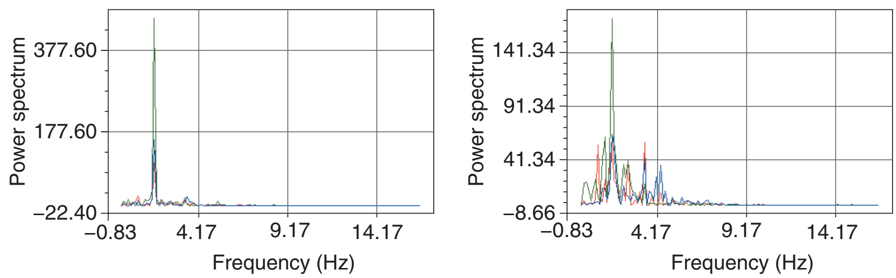
The second feature creates an easy-to-understand graphical visualization combining time and location information. Walking is greatly influenced by the surrounding environment, so location information can be very meaningful. This feature clearly shows when and where the subject was walking. By including location information, the system records the range of user activity as well as the type of walking.

A schematic of this system is shown in **Fig. 2**. The user carries a mobile phone with the data-collection application installed at all times. The software collects GPS and accelerometer data periodically and automatically sends it to the server, which accumulates it as a lifelog. The lifelog can be viewed on the server through the Internet by the patient himself, medical staff, or other authorized persons.

Visualizations of the movement log collected while the same person walked over the same course under two different conditions are shown in **Fig. 3**:

(a) Normal walking (b) Constrained walking

Fig. 3. Movement log.



(a) Normal walking (b) Constrained walking

Fig. 4. Walking smoothness.

(1) Normal walking (Fig. 3(a)).
(2) Walking with constraints attached to the right knee and ankle that limited their movement range (Fig. 3(b)).

The walking course began in the lower right of the map and was approximately 3 km in length. The total change in elevation was about 100 m, with particularly steep inclines toward the end of the course. The marks along the course indicate the person's walking pace, with the fastest pace shown in red and the color changing to green and blue as the pace decreased. In the normal walking case, the pace was initially fast after the start and slowed as walking continued. In contrast, in the constrained walking case, the pace was not fast after the start and became slower much earlier, as indicated by the change to blue markers.

An example of a detailed analysis of walking at the same location in each case (the middle points in Fig. 3) is shown in **Fig. 4**. In this example, the smoothness of walking was analyzed by taking the fast Fourier transform of the acceleration signals to compute their frequency components. The graphs show that in the normal walking case there were almost no frequency components other than the walking pace, while the constrained case contained various other frequency components. This result shows that wearing the constraints on the right leg was a hindrance to smooth walking.

Data can be gathered automatically in this way without placing a burden on the user, and a visualization of normal walking behavior can be created. Compared with conventional measurements of walking made in a medical facility, these measurements cover a much greater extent in both time and space, so this normal activity data can be used to understand patient rehabilitation and recovery conditions. It should also be useful for preventive care and capturing symptoms such as weakening legs or declining activity levels in elderly subjects.

3. Future developments

We intend to develop these lifelog-gathering experiments further by increasing the number of subjects in vital-data experiments and building mechanisms that make it easier to maintain patient motivation for collecting lifelog data. We will also continue to study ways of linking medical information systems at medical facilities to these lifelog services. We plan to conduct experiments on the gait visualization technology in the fields of preventive care and rehabilitation in cooperation with Kyoto University Hospital to study its effectiveness in these areas.

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Complex Data Analysis Using Mixture Models

Katsuhiko Ishiguro†

Abstract

In this article, I discuss mixture models, which are very popular for the analysis of complex data. A mixture model represents the given data as a mixture of K components, each of which has different characteristics. First, I explain a standard mixture model, which requires K to be specified. Then, I introduce a nonparametric Bayes-extended mixture model that avoids this shortcoming and describe its effectiveness, which was briefly assessed in a small simulation experiment. Finally, I present an application of the mixture model for understanding movie scenes.

1. Introduction

Nowadays, many people enjoy a vast amount of digital data such as text, images, music, and videos downloaded from the Internet via broadband network access. Surveillance cameras automatically capture public scenes every day, and these videos are stored in huge data repositories. In stock markets, automated computer agents generate a huge amount of transaction records for every second.

Since the available datasets are so huge that no human can analyze them manually, many researchers have tried to use statistical and probabilistic models to analyze their complex properties. Typically, these models represent complex data by a stochastic process (model) with a few parameters. These parameters are tuned (trained) by machine learning [1] techniques to explain the observed data as much as possible: the idea is that if we can explain the observation set well, we may have some confidence that the learned parameters and the chosen model represent (part of) the essence of the data.

Many statistical models have been proposed for complex data analysis. One of the most popular techniques uses mixture models, which have proven to be very useful in many studies and domains. A mixture model assumes that the observed data are generated by a small number of hidden components, each of which has different parameters (characteristics). The model estimates the properties of this *mixture* of hidden components from the given data.

This article explains the idea and the usefulness of mixture models and their extension for complex data analysis. It also introduces an application of the mixture model to the field of computer vision for target tracking. Section 2 explains a standard mixture model using an example of movie scene understanding. Section 3 introduces a recent mixture model extension. Section 4 reports research by my colleagues and I on target tracking and shows some results.

2. Mixture model

Assume that we have a camera that captures an ordinary scene of pedestrians on a street in Tokyo. Many people are visible in the scene. The captured images include many human activities: some people are just walking, but their walking directions and speeds are different; a few business people walk rapidly while using cell phones; and some kids are running around. How can we *model*, or represent, such complex information with a statistical model?

The mixture model assumes that these complex data are generated by a number of different *sources*. Each source is called *a component*, characterized by a unique pattern of data outputs. We understand the given data as the mixture of these different patterns

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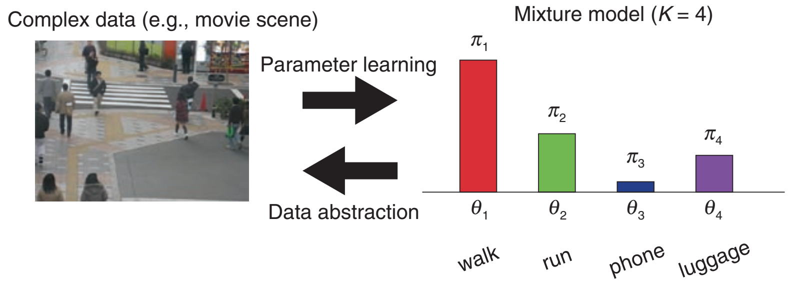

Fig. 1. Illustration of mixture model.

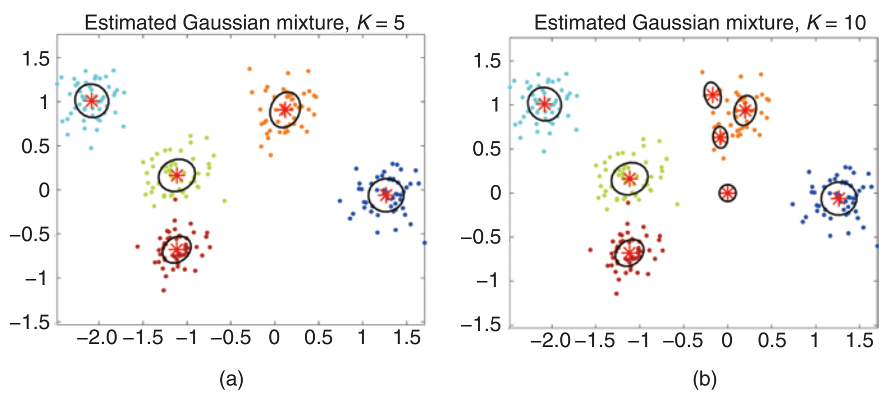

Fig. 2. Mixture model results estimated from 2D data points with (a) the correct $K = 5$ and (b) an incorrect $K = 10$. Three components overlap at (0, 0) in (b).

generated from the multiple components. In this example, people are generating the visual stimuli. We assume that personal behavior can be categorized into a manageable number of patterns: walking, running, using cell phones, carrying luggage, etc. A complex scene with a number of people can be decomposed into several behavior patterns. That is, a captured video can be understood as a (complex) mixture of these different sources (**Fig. 1**).

More technically, the mixture model assumes that K hidden (latent) components with different parameters (characteristics) θ_k underlie the observed data $X = \{x_i\}$. Each portion of the observed data is generated from one of these hidden components, and the total amount of data generated by component k is defined by its mixing ratio π_k. The model is formulated as follows:

$$p(X) = \prod_i \sum_{k=1}^{K} \pi_k p(x_i|\theta_k), \qquad (1)$$

where $p(x)$ denotes the probabilistic density function of predicate x and

$$\sum_{k=1}^{K} \pi_k = 1, \pi_k > 0.$$

We tune (learn) the parameters θ_k and the mixing ratios π_k of these hidden components in order to approximate the given observed data. This parameter learning can be carried out automatically by maximizing a standard evaluation function.

Some results of using a mixture model to analyze a set of two-dimensional (2D) points are shown in **Fig. 2**. The small colored dots denote data points. The dataset is assumed to be generated by five mixture components. Each point is generated from one of the five components where its color indicates the source component. Each component is modeled as a 2D Gaussian distribution and generates 50 data points. Red stars and corresponding black ellipses indicate the means and standard deviations of estimated Gaussian components yielded by the Gaussian mixture model. K is fixed and the model is fitted using the variational Bayes method [1], which is an iterative computation technique. Figure 2(a) is the result when the correct value of $K = 5$ was chosen, while Fig. 2(b) shows an example of an incorrect value, $K = 10$. As shown, the mixture model can derive reasonable mixture component distributions if the specified K is correct.

Mixture models are basic yet practical tools in many problems in several domains. For example, a mixture model can be used to describe the background scenes of a movie [2]; the key advance is distinguishing the foreground objects that are the focus of attention from the background. Since the background has many different surfaces and planes, its pixel values can be effectively modeled by a mixture of different pixel value components. A mixture model has also been used for automatic speaker recognition in recorded sounds [3].

3. Infinite mixtures obtained by nonparametric Bayes models

One problem with using mixture models is that we have to determine K in advance. In general, specifying the correct K is very difficult, and using the wrong value of K may degrade model fitting very badly, as seen in the example (Fig. 2(b)). One popular solution is to use an information criterion for choosing the best K, i.e., AIC [4] or BIC [5]. In this case, we prepare several mixture models with different K values and compute the criteria for each learned model.

Recently, another solution, called the nonparametric Bayes approach, has been developed. It does not demand that K be specified. Instead, the model chooses an appropriate value for K to explain the given data in a probabilistic manner.

In this article, I introduce the Dirichlet Process Mixture (DPM) model, a nonparametric Bayes extension of usual mixture models. Mathematically, DPM represents a mixture of infinitely many components (**Fig. 3(a)**). Thus, it has the potential to fit any mixture. It assumes many possible mixture structures G^1, G^2, …, probabilistically (**Fig. 3(b)**). Some mixtures have higher probabilities and others have lower probabilities. In practice, we have only a finite amount of data information: i.e., the number of components cannot be infinite. DPM chooses the most appropriate mixture structure—the values of K and π_k—from infinitely many candidates.

A more mathematically precise explanation is given below. Formally, DPM is based on the Dirichlet process, which is a stochastic distribution of distributions. However, explaining how DPM can be based on a Dirichlet process is not intuitive in the context of the mixture model. Therefore, I explain DPM from the mixture model viewpoint. The resulting probabilistic distribution of parameters θ is described as follows:

$$G(\theta) = \sum_{k=1}^{\infty} \pi_k \delta_{\theta_k}(\theta), \quad (2)$$

$$p(\pi_k) = Stick(\gamma),\ k = 1, 2, ... \quad (3)$$

There are two points to note. First, index k imposes no upper limit on K in the summation in Eq. (2). This indicates that DPM is an infinite mixture model. Second, Stick(γ) is a stochastic process called the stick breaking process [6]. The stick breaking process (Eq. (3)) randomly generates an infinite number of positive scalars that are summed to one. More precisely, Stick(γ) generates π_k according to the following equations:

$$\pi_1 = v_1\ , \quad (4)$$

$$\pi_k = v_k \prod_{l=1}^{k-1} (1-v_l),\ k > 1 \quad (5)$$

$$p(v_k) = \mathrm{Beta}(1, \gamma). \quad (6)$$

This indicates that the structure of the mixture, including the number of components and their mixing ratios, is defined in a stochastic manner rather than a deterministic manner: that is, it is defined on the basis of sampling from the Beta distribution. Note that π_k rapidly decreases as k becomes large because of the product of v_k. Therefore, the stick breaking process inherently offers a clustering function: the process does not want the mixing ratios to be large for many of the components. Given $G(\theta)$, the observed data $X = \{x_i\}$ is modeled in the same way as the original mixture models, except for an infinite number of components:

$$p(X) = \prod_i \sum_{k=1}^{\infty} \pi_k p(x_i|\theta_k). \quad (7)$$

One reason for using DPM is that the number of clusters automatically scales with the data complexity, and we can automatically find a mixture with an appropriate number of components using a standard Bayes (probabilistic) machine learning technique. As noted, by using DPM we can avoid the need to specify the number of mixture components, a key weakness of mixture models.

Another advantage of DPM is that it provides an

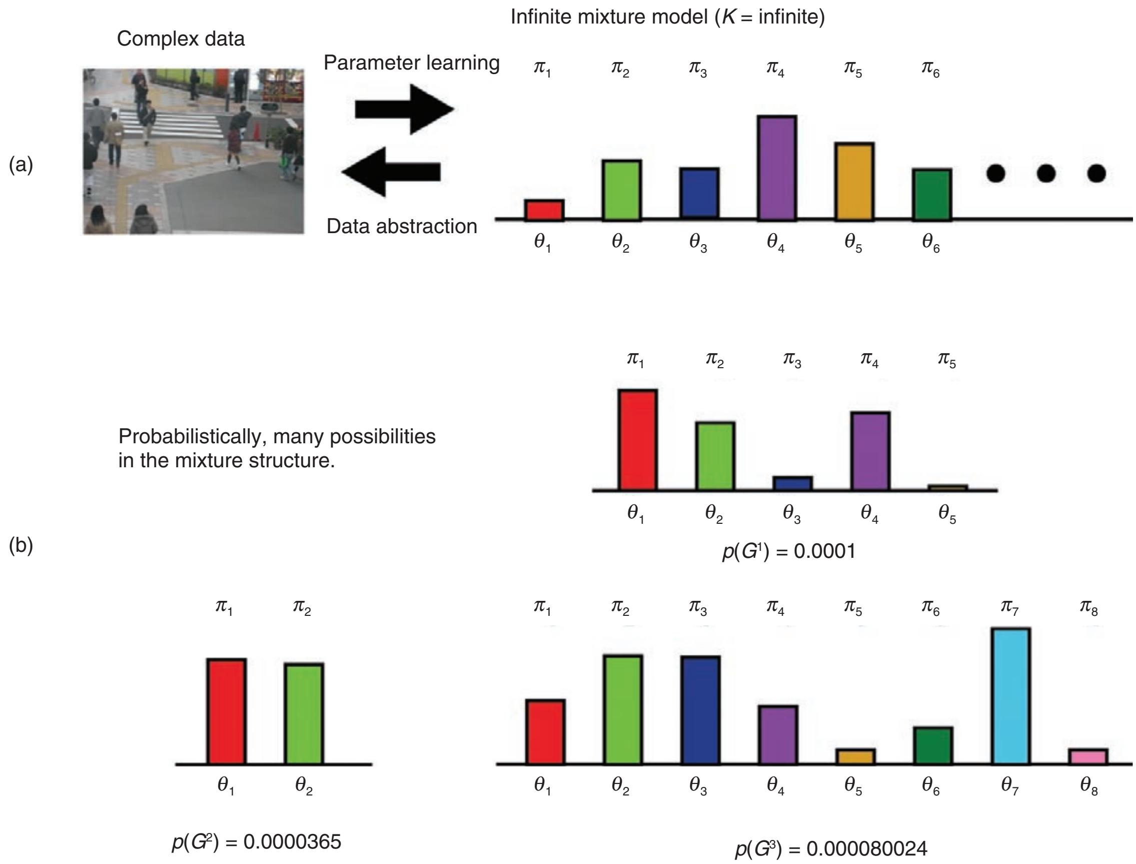

Fig. 3. Illustration of DPM model.

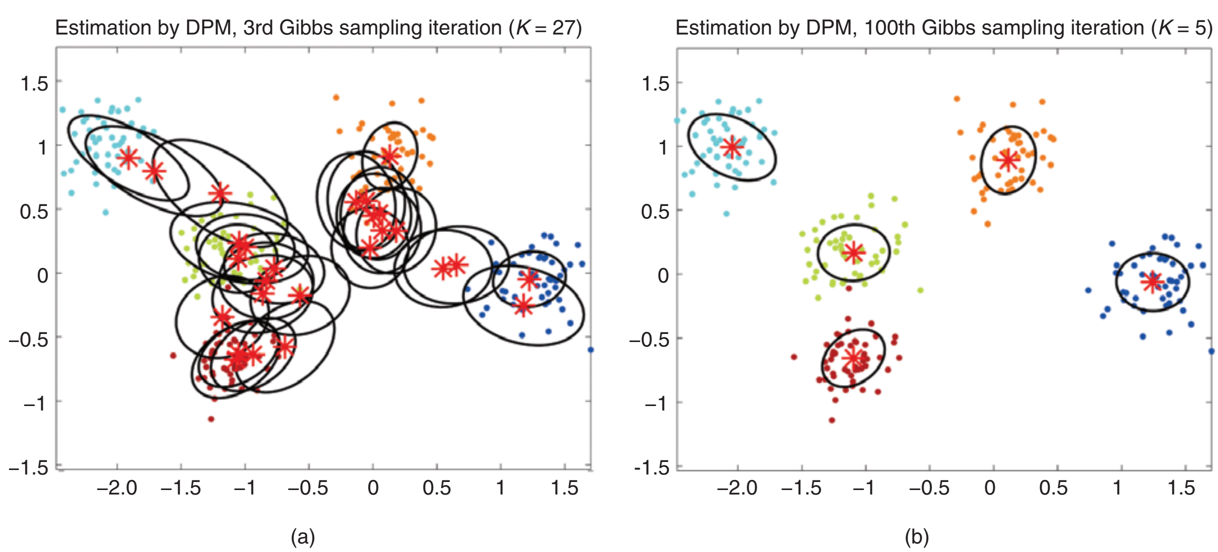

Fig. 4. Mixture model results estimated from 2D data points by using DPM. (a) An early result (third iteration). The inference has not converged yet, and the estimation is not good. (b) After convergence of the Gibbs sampling, the correct mixture structure with $K = 5$ components was recovered automatically.

easy and convenient formulation. Implementing the above infinite equations (Eqs. (2) and (3)) in a program (with finite memory) is difficult. One solution is the Chinese restaurant process (CRP) [7]. In CRP, each observed datum (point) is assigned to one of the mixture components. Let us denote the assignment of the ith item x_i to the kth component as $z_i = k$. Moreover, let us denote the total number of data as N. In CRP, we use the following rules to determine z_i:

$$p(z_i = k | z_{1:N \neg i}) \propto \begin{cases} n_k, & 1 \le k \le K \\ \gamma, & k = K+1 \end{cases} . \quad (8)$$

This equation computes the probability of the ith datum being assigned to the kth component under the condition that the assignments of all other data are fixed. Here, n_k denotes the number of items assigned to the kth component and K denotes the number of components, counted via N-1 assignments. CRP assigns the ith datum to the kth component with a probability proportional to the component's membership. The probability of a new K+1th cluster being generated is proportional to γ.

We repeat this process many times with different values of i and achieve assignments for all data. During the process, the number of mixture components varies. It is known that CRP-based DPM is truly equivalent to the formal infinite representations of Eqs. (2) and (3).

A simulation result for DPM is presented in **Fig. 4**. We tested the same dataset as used in Fig. 2 and estimated the hidden mixture structure by using DPM. We used a CRP representation of DPM and chose Gibbs sampling [1] as the inference algorithm. Figure 4(a) shows a result in an early iterative step and Fig. 4(b) is the final result indicated by the convergence of the Gibbs computation. As can be seen, DPM obtained the correct $K = 5$ mixture components. Let me emphasize again that there was no need to specify the initial value of K: the model automatically found the best K to represent the given data.

Because of this advantage, many researchers have applied DPM to many problems, including community detection from network data [8] and document (natural language) modeling [9].

4. Application: multi-target tracking with movement pattern discovery

Here, I describe our work on using the mixture model to understand visual scenes. Many developed countries and major cities have visual surveillance cameras for security. These cameras are useful for deterring crimes and the captured data can be used to identify accidents or criminal activities. However, it is said that surveillance cameras, by themselves, are not so effective in deterring truly committed criminals or terrorists. Detecting anomalous activities as precursors to illegal acts still requires human eyes and it is impossible for all cameras to be adequately covered by human observers.

To enable automatic analysis of video streams, many researchers have studied the problem of action recognition and scene understanding; for example, identifying suspicious activities. The technique of tracking, which is one of the hot research topics in this field, is intended to locate and follow particular people against various backgrounds. More technically, tracking should determine the parameters of the objects of focus such as their locations and postures. The most common security concern is to track humans (in many cases, pedestrians), and many studies have, of course, addressed this task (e.g., [10]–[15]).

The outputs of surveillance cameras contain many patterns or target movements: the targets run, walk, and turn at various speeds and in various directions, and objects change their movement to avoid collisions and follow signals. However, many tracking models assume that the movement patterns of the targets (pedestrians) are invariant. Detecting such changes in movement patterns will yield more precise tracking. One problem is that we do not know the exact, or best, number of such movement patterns. Moreover, it is clear that these patterns are context-dependent: different patterns are exhibited at airports, train stations, and shopping malls and on the street.

We have developed a tracking algorithm that can solve these problems by using the DPM model [16]. Using DPM, we can automatically obtain an appropriate number of *movement patterns* that fit the scene's context. Our developed model can also learn these patterns in an online manner: in other words, it discovers a novel pattern appearing in a video at first sight.

We tested our model with three datasets: one simulated and two real video sequences. A quantitative result using log likelihood as a data fitness measure is shown in **Fig. 5**. Our model outperformed a conventional model, which was unable to discover movement patterns.

A tracking result for an actual video sequence is shown in **Fig. 6**. Colored rectangles indicate the tracked targets, and the number above the rectangle is the movement pattern index for that frame. As you

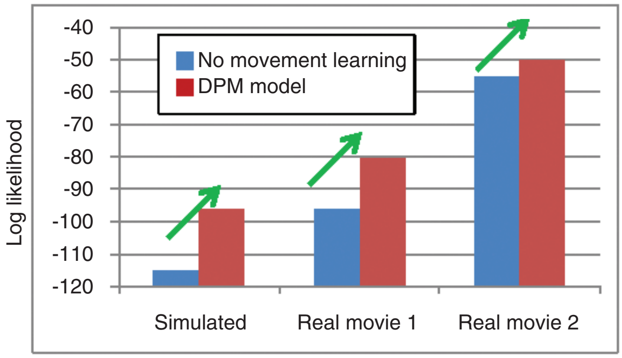

Fig. 5. Log likelihood comparison results. Larger log likelihoods are better.

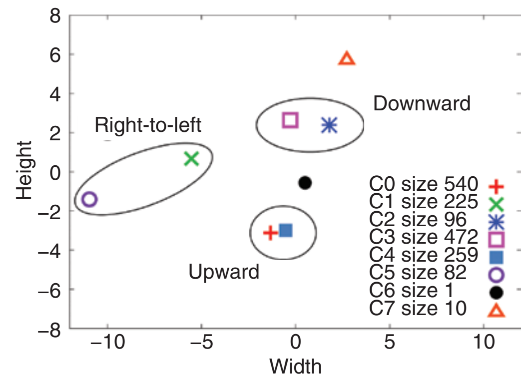

Fig. 7. Movement patterns discovered by DPM. Size indicates how many times pattern Ci occurred in the movie.

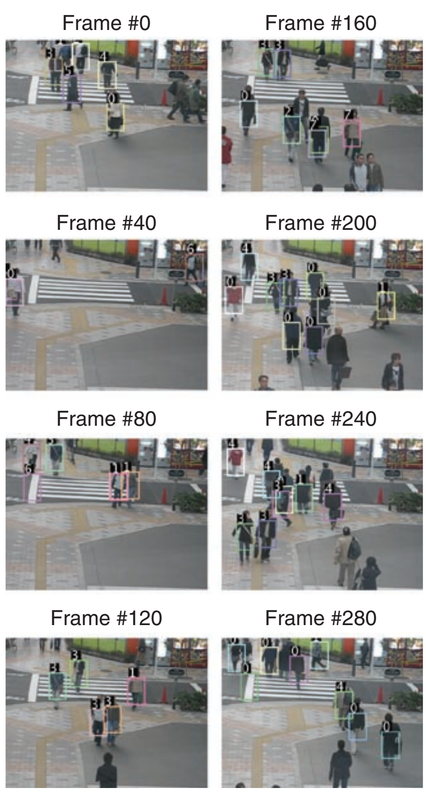

Fig. 6. Tracking results obtained by DPM.

can see, a target can exhibit different movement patterns over time.

The discovered movement patterns θ_k for the same dataset are shown in **Fig. 7**. We found six major movement patterns. Upward and downward movements had two subpatterns, corresponding to leftward or rightward movements. Right-to-left movements exhibited a slow movement pattern (green cross) while a fast movement pattern had fewer instances (purple circle). This differentiation well matches the actual sequence: a few persons walked rapidly, but the majority walked slowly. Note that these movement patterns were automatically discovered by the infinite mixture model based on DPM.

5. Conclusions

In this article, I introduced mixture models for analyzing complex data such as video sequences. A standard mixture model, used in many applications, uses a fixed number of mixture components K. DPM is a recent development that assumes (mathematically) an infinite number of mixture components and can therefore adapt to unknown mixtures. My colleagues and I have applied DPM to the target tracking problem. Our system automatically learns movement patterns, and tests showed that it achieved better tracking precision than the conventional solution.

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Standardization Trends for Optical Transport Network Technologies in ITU-T

Eiji Yoshida†, *Kazuhide Nakajima, Noriyuki Araki, and Yusuke Koshikiya*

Abstract

In this article, we explain recent standardization trends in ITU-T SG15 WP2 (International Telecommunication Union, Telecommunication Standardization Sector; Study Group 15; Working Party 2) for optical transport network technologies such as optical transmission and optical fibers and cables to support the increase in data traffic resulting from new services using the optical broadband network and the evolution of high-speed Ethernet.

1. Background

Working Party 2 (WP2) in ITU-T SG15 (International Telecommunication Union, Telecommunication Standardization Sector; Study Group 15) is responsible for standards for optical transport network technologies including network infrastructure, systems, equipment, and optical fibers and cables and their related installation, maintenance, and measurement techniques. WP2 is currently handling seven Questions; their titles are as follows.

Q5: Characteristics and test methods of optical fibers and cables
Q6: Characteristics of optical systems for terrestrial transport networks
Q7: Characteristics of optical components and subsystems
Q8: Characteristics of optical fiber submarine cable systems
Q16: Optical physical infrastructure and cables
Q17: Maintenance and operation of optical fiber cable networks
Q18: Development of optical networks in the access area

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The international standards related to these fields play an important role in the development of the industry. Here, we focus on the 40G/100G optical interface (40G and 100G are names denoting data transmission rates that are close to 40 and 100 Gbit/s, respectively), optical transmission to support the evolution of FTTx (fiber to various different termination points), etc., which are hot topics these days.

2. High-speed Ethernet and OTN optical interface

Q6 is responsible for developing standards for optical interfaces for terrestrial transport networks, excluding the access network. First, we explain high-speed Ethernet and the related optical interface for the Optical Transport Network (OTN). Ethernet is standardized in IEEE802.3ba and its main target is local area networks (LANs). On the other hand, OTN is standardized in ITU-T and its main target is wide area networks (WANs). A high-reliability, high-capacity, long-distance optical transport network based on wavelength division multiplexing (WDM) technology can be achieved by using OTN technology.

40G Ethernet and 100G Ethernet were standardized in June 2010. Their notable feature is multilane

Table 1. Relationship between the optical interfaces of Ethernet and OTN.

Ethernet (for LANs)		OTN (for WANs)	
Standard (distance)	Specifications	Recommendation (application code)	Specifications
40GBASE-LR4 (10 km)	10.31 Gbit/s x 4 wavelengths 1300-nm band WDM with 20-nm spacing (CWDM)	G.695 (C4S1-2D1)	10.75 Gbit/s x 4 wavelengths 1300-nm band WDM with 20-nm spacing (CWDM)
100GBASE-LR4 (10 km)	25.78 Gbit/s x 4 wavelengths 1300-nm band WDM with 800-GHz spacing	G.959.1 (4I1-9D1F)	27.95 Gbit/s x 4 wavelengths 1300-nm band WDM with 800-GHz spacing
100GBASE-ER4 (40 km)	25.78 Gbit/s x 4 wavelengths 1300-nm band WDM with 800-GHz spacing	G.959.1 (4L1-9C1F)	27.95 Gbit/s x 4 wavelengths 1300-nm band WDM with 800-GHz spacing

transmission such as 4 × 10G and 4 × 25G. The standards for Ethernet targeted at single-mode fiber (SMF) transmission are listed in **Table 1.** OTN currently has four line rates defined by optical channel transport units (OTUs). The OTU4 frame, which can accommodate a 100G Ethernet signal transparently, was standardized in ITU-T Recommendation G.709. The OTU frame is composed of a payload, overhead for administration, and bits for forward error correction. The bit rate of the OTU4 frame is 111.8 Gbit/s. Optical interfaces for parallel transmission of 40G and 100G signals based on G.709 were standardized in Q6 with a view to enabling the utilization of Ethernet optical modules considering demands for low costs. Recommendation G.695 specifies the optical interface for coarse WDM (CWDM) and a new application code was added for 40G, 10-km transmission using four wavelengths, which is related to 40G Ethernet. The bit rate carried by each wavelength is 10.75 Gbit/s (10.75 Gbit/s × 4 wavelengths). Recommendation G.959.1 specifies an inter-domain interface for optical networks and new application code was added for 100G, 10-km and 40-km transmission using four wavelengths, which is related to 100G Ethernet. The bit rate carried by each wavelength is 27.95 Gbit/s (27.95 × 4 wavelengths).

3. 40G/100G high-speed optical interface

The modulation format in optical transmission systems that has been considered so far in ITU-T is non-return to zero (NRZ). NRZ is a binary on-off keying that represents a digital signal 0 or 1 according to the intensity of the optical signal. However, in serial high-speed, long-distance transmission of 40 Gbit/s or more, it is important to improve receiver sensitivity, wavelength dispersion tolerance, and polarization mode dispersion (PMD) tolerance, so various modulation formats have been researched and developed to overcome these problems. Against this background, Q6 started to investigate new modulation formats in 2007 and, as a result, differential phase shift keying (DPSK), differential quadrature phase shift keying (DQPSK), polarization-multiplexing QPSK (PM-QPSK), which is also called dual-polarization QPSK, orthogonal frequency division multiplexing (OFDM), etc. were added to Supplement G.Sup39 in 2008. Note that G.Sup39 is not a Recommendation but describes design and engineering considerations for optical transmission systems as a supplement. DPSK is a binary phase modulation in which phase differences of 0 and π between adjacent optical signals correspond to digital signals 0 and 1, respectively. It can increase the receiver sensitivity by approximately 3 dB. DQSK is a four-level phase modulation in which phase differences of 0, $\pi/2$, π, and $3\pi/2$ correspond to digital signals 00, 10, 01, and 11, respectively. It can not only increase the receiver sensitivity but also transmit two bits per signal. This means that it can halve the required electrical interface speed, or in other words, it allows a transmission capacity that is double the symbol rate. DQPSK has the advantage of increasing the wavelength dispersion tolerance, PMD tolerance, and spectral efficiency. PM-QPSK is a format that combines QPSK with polarization division multiplexing. It can reduce the symbol rate to one quarter. If digital coherent technology is used in the receiver, the sensitivity is more than 3 dB higher, and waveform distortion due to wavelength dispersion and PMD can be compensated for electrically. In OFDM, several subcarriers are generated and multiplexed in the frequency domain. OFDM can decrease the symbol rate in proportion to the number of subcarriers. The symbol rates and constellation diagrams

Modulation format	NRZ	DQPSK	PM-QPSK	OFDM-QPSK
Symbol rate (GBaud)	112	56	28	28

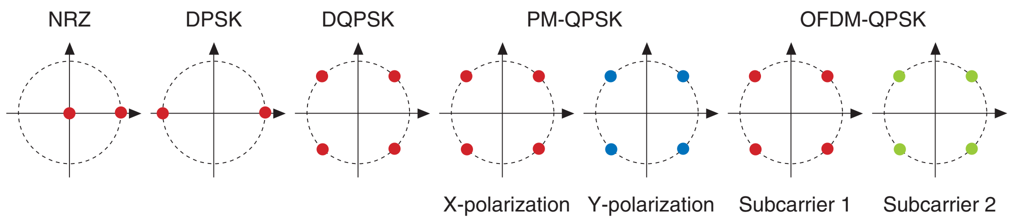
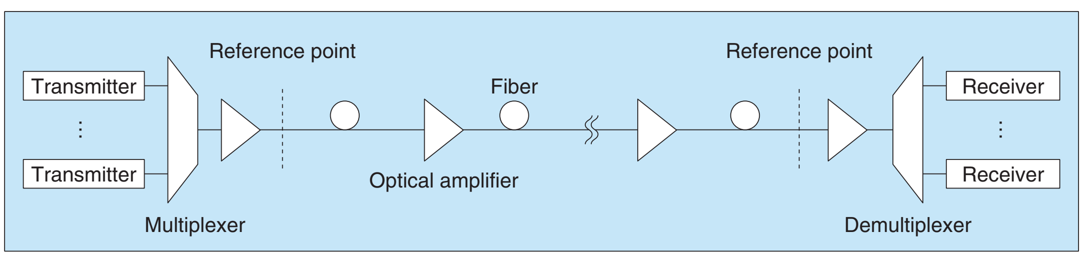


Fig. 1. Symbol rates (for OTU4) and constellations of various modulation formats.



Application code: n.B-xWF(s)
n: maximum number of channels
B: bit rate (1.25G, 2.5G, 10G, 40G, 100G)
x: number of spans
W: span attenuation (S: 11 dB, L: 22 dB, V: 33 dB)
F: fiber type (G.652, G.653, G.655)
S: wavelength band (S, C, or L band)

Fig. 2. Configuration example of WDM system and application code (G.696.1).

of several modulation formats are shown in **Fig. 1**, for OTU4 (112 Gbit/s) as an example. In a constellation diagram, the x and y axes represent the in-phase and quadrature-phase components of the signal, respectively.

40G systems using DPSK or DQSK have recently been introduced in optical metro and backbone networks on the market. 40G optical interfaces with new modulation formats are currently being examined in ITU-T, especially with the aim of conforming to Recommendation G.698.2, which provides optical parameter values for the physical layer interfaces of DWDM systems intended primarily for metro applications including optical amplifiers, targeting multivendor compatibility. Q6 has started to discuss how to specify an extinction ratio and an eye mask in terms of phase modulation because new specifications are needed for them.

The standard for 100G serial optical interfaces has also been discussed in ITU-T. The addition of 100G application code to Recommendation G.696.1 (an NTT proposal) was given consent in the plenary meeting in June 2010. G.696.1 provides physical layer specifications for intra-domain DWDM systems targeting longitudinally compatibility. A configuration example of a multi-span DWDM system and its application codes are shown in **Fig. 2**. The application code previously had only four bit rates: 1.25G, 2.5G, 10G, and 40G. It was extended to 100G for the first time. The characteristics of a 100G signal using the PM-QPSK format and digital coherent detection are described in Appendix I of G.696.1 as

Table 2. Categories of bending-loss insensitive fiber for access networks (G.657).

		Minimum allowable bending radius		
		Type 1 15 mm	Type 2 7.5 mm	Type 3 5 mm
Compatibility with SMF	Type A: perfectly	A1 (specified)	A2 (specified)	A3 (not specified)
	Type B: partially	B1 (not specified)	B2 (specified)	B3 (specified)

an application example.

Another topic that Q6 is treating is all-optical networks. Recommendation G.680 defines a degradation function for optical network elements considering impairments such as optical noise and chromatic dispersion. This Recommendation is now targeting reconfigurable optical add-drop multiplexers (ROADMs).

Q7 is responsible for the standard for the characteristics of optical components and subsystems. The latest topics include PMD compensators and optical components for phase modulation systems.

Moreover, Q8 has considered revising two Recommendations on the characteristics of repeaterless optical fiber submarine cable systems (G.973) and optically amplified optical fiber submarine cable systems (G.977) in response to increases in transmission capacity. It has also considered revising the Recommendations on optical fiber submarine cables (G.978) and test methods applicable to optical fiber submarine cable systems (G.976), which are needed for constructing and operating the systems because they need to provide higher service reliability.

In recent years, the assurance of interoperability has become one of the most important issues. A new Recommendation, G.973.1, for longitudinally compatible DWDM applications for repeaterless optical fiber submarine cable systems was created in November 2009. Q8 intends to continue discussing system interoperability in order to provide systems that are more cost effective.

4. Optical fibers and cables

The characteristics of optical fibers used for current SMF communication have been defined in five Recommendations: G.652–656. So far, Q5 has created and revised some Recommendations on optical fibers, e.g., optimization of descriptions of chromatic dispersion characteristics of G.65x fibers, in synchronization with considerations on optical transmission technologies in Q6. The characteristics of SMF, which is most generally used in current optical access and core networks, are defined in G.652.

When SMF is bent with a bending radius of several tens of millimeters, it suffers from optical bending loss at bend. Therefore, the development and standardization of bending-loss insensitive fibers have received broad attention. In response Q5 created Recommendation G.657 on the characteristics of the bending-loss insensitive SMF for access networks in 2006. At that time, a major topic of discussion was a bending-loss insensitive fiber that allowed a bending radius of 15 mm, which is half the allowable bending radius of conventional SMF. In December 2009, Q5 created the second edition of G.657, which covers bending-loss insensitive fiber that allows a bending radius of 5 mm, in response to a request to support the provision of cost-effective unskilled optical fiber distribution.

In general, there is a trade-off between the bending loss characteristics and the mode field diameter (MFD) for SMF. If the bending loss characteristics are improved, the MFD becomes smaller, which in turn causes an increase in the connection loss. Therefore, as listed in **Table 2**, G.657 defines fiber categories considering compatibility with the conventional SMF and minimum allowable bending radii. There are four fiber categories. Standardization of category A3 has been continuously discussed along with the research and development of bending-loss insensitive fibers. Another important issue is to clarify the mechanical reliability of optical fibers bent with a small radius, so Q5 revised the appendix of G.657, which deals with the reliability of optical fibers. In Q5, discussion of reliability is now underway in cooperation with Q16 and the International Electrotechnical Commission (IEC).

Q5 has also studied test methods for SMF (G.650.1–650.3). G.650.1 and 650.2 deal with test methods for linear and nonlinear attributes of SMF, respectively. These are used to evaluate SMF transmission

Table 3. Maintenance wavelength allocation (L.41).

	1310-nm band	1550-nm band	1625-nm band	1650-nm band
Case 1	Active	Vacant or maintenance	Vacant or maintenance	Vacant or maintenance
Case 2	Vacant or maintenance	Active	Vacant or maintenance	Vacant or maintenance
Case 3	Active	Active	Vacant or maintenance	Vacant or maintenance
Case 4	Active or vacant	Active	Active	Vacant or maintenance

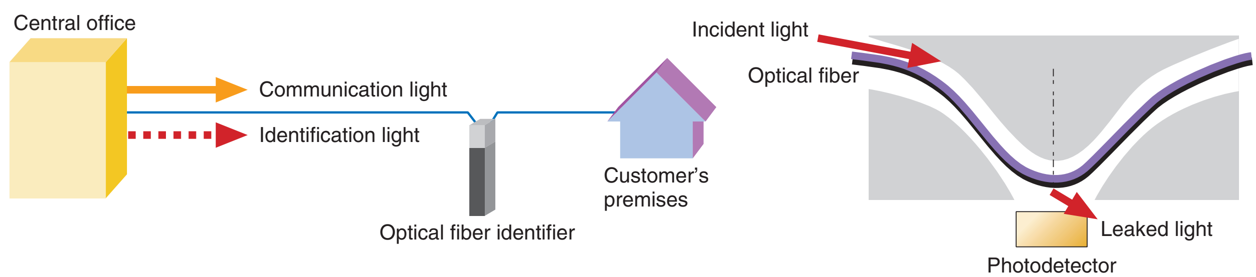


Fig. 3. Optical fiber identification technique (L.85).

characteristics. G.650.3 deals with test methods for transmission lines. Further discussion about such test methods is expected for the development of FTTx as the use of optical fibers grows.

On the other hand, recommendations for various optical fiber cables have been studied in Q16. Recommendation L.87 on an optical drop cable consisting of bending-loss insensitive fibers defined by G.657 was created. This was in response to a request to support the installation of small-bending-radius optical fiber cables. The drop cable allows an aesthetic and flexible distribution of optical fiber cables in subscriber premises. L.87 describes the characteristics and construction and test methods (mainly following IEC standards) of optical fiber cables for drop applications. Q16 decided to ask IEC SC86 WG3 to standardize test methods for cables bent with a small radius because there was a comment about the need for test methods in the course of the discussion.

5. Optical fiber cable networks

Q17 has examined recommendations related to the maintenance and operation of optical fiber cable networks. Recommendations L.25, 40, and 53 define fundamental requirements for optical fiber network maintenance, an optical fiber testing system, and maintenance for passive optical networks and ring networks, respectively. Moreover, recommendations related to the allocation of a maintenance wavelength and maintenance criteria for in-service fiber testing in access networks are described in L.41 and 66. **Table 3** shows which communication bands have maintenance wavelengths allocated in them as defined in L.41. In-service fiber testing can be conducted irrespective of the service type by using 1650 nm (in the U-band) as the maintenance wavelength even when bands O–L (1260–1625 nm) have been allocated to service provision.

An optical fiber identification technique is important in maintaining network reliability and operating an optical fiber network effectively. It lets us distinguish the target fiber from among many fibers. Q17 created Recommendation L.85 on this optical identification technique in July 2010. As shown in **Fig. 3**, this Recommendation describes the method specified in this Recommendation using a non-destructive macrobending technique. An identification light is injected into the target fiber from the end of an optical fiber line (e.g., a central office) or is introduced by using optical devices for testing (e.g., an optical coupler). This identification light has a different wavelength from the communication light carrying the data signal. The optical fiber identifier bends the optical fiber, and a photodetector located at the center of the bent part detects the modulated identification light leaking from the bent fiber. L.85 defines requirements for optical fiber identification, which were based on L.41 and 66 for in-service line testing.

Q17 is also studying requirements for systems that monitor outside plant facilities. It is planning to create Recommendations for natural disaster countermeasures for outside plants.

Q18 is studying a configuration for passive optical networks (PONs), which have become a major topology class for optical access networks. A Recommendation for providing cost-effective efficient FTTx is expected because this is an important global issue. In response to a request, Recommendation L.86 describing considerations on installation sites for branching components in PONs for FTTH (fiber to the home) was published in 2010.

6. Future efforts

ITU-T SG15 WP2 is currently undertaking a wide range of activities such as producing a handbook containing outlines of Recommendations created by WP2. NTT will continue to contribute to international standardization of optical transport network technologies including optical transmission technology, which will have higher-speed interfaces in line with optical network evolution, and optical fiber line technologies.

Acknowledgment

The efforts to have the 100G serial optical interface technology adopted as an international standard are partly supported by the Universal Link Project of the National Institute of Information and Communications Technology (NICT) of Japan.

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The Green Vision 2020—
The New Vision for Environmental Protection Pursued by the NTT Group

Under the NTT Group Global Environment Charter, we have been pursuing conservation of the global environment and will be achieving all the targets we promised by the end of 2010 in the three important issues, namely, global warming prevention, reduction of waste, and reduction of paper consumption.

Now, we have established the new Green Vision 2020 that includes "conservation of biodiversity" in addition to the basic policy of the NTT Group Global Environment Charter.

From now on, all members of the NTT group will make concerted efforts together to achieve The Green Vision 2020.

* The details of The Green Vision 2020 will appear as Feature Articles 2 in the April 2011 issue of the NTT Technical Review.

External Awards

IEEE International Conference on Broadband Network & Multimedia Technology (IEEE IC-BNMT 2010) Best Paper Award
Winner: Daisuke Ikegami and Toshiaki Tsuchiya, NTT Service Integration Laboratories
Date: Oct. 28, 2010
Organization: IEEE

For "Evaluating TCP Throughput and Packet Size Under Policing Environment".

Papers Published in Technical Journals and Conference Proceedings

Numerical Analysis of Singularity Exponent for Sharp Corners

T. Shibata

Proc. of the Microwave Conference 2009, APMC 2009, Asia Pacific, pp. 838–841, Singapore, Dec. 2009.

The singularity behavior of an electromagnetic field near sharp edges and corners has been a crucial topic in microwave field theory and analyses. The magnitude of field components in the neighborhood of a sharp corner may increase rapidly as the point approaches the tip, which can be expressed in terms of ρ** (τ-1), where ρ represents the distance from the tip of the corner and τ is a characteristic value of the exponent, which depends on materials and the local structure of the corner. Having the τ values for various corners as preliminary knowledge, we can devise more accurate and more efficient analyses of microwave problems. This paper presents an improved numerical analysis method for τ of complex corners based on finite-difference simulation.

High-speed Circuit Technology for 10-Gb/s Optical Burst-mode Transmission

Y. Ohtomo, H. Kamitsuna, H. Katsurai, K. Nishimura, M. Nogawa, M. Nakamura, S. Nishihara, T. Kurosaki, T. Ito, and A. Okada

Proc. of Optical Fiber Communication (OFC), collocated National Fiber Optic Engineers Conference, 2010 Conference on (OFC/NFOEC), pp. 1–3, San Diego, CA, USA, Mar. 2010.

A careful choice of burst-mode 3R receiver circuits achieves fast settling of 200 ns and low power of 1.68 W as well as the optical sensitivity and dynamic range in the 10G-EPON specification.

Parametric Packet-layer Model for Evaluating Audio Quality in Multimedia Streaming Services

N. Egi, T. Hayashi, and A. Takahashi

IEICE Trans. on Commun., Vol. E93-B, No. 6, pp. 1359–1366, 2010.

We propose a parametric packet-layer model for monitoring audio quality in multimedia streaming services such as Internet protocol (IP) television. This model estimates audio quality of experience on the basis of quality degradation due to coding and packet loss of an audio sequence. The input parameters of this model are audio bit rate, sampling rate, frame length, packet-loss frequency, and average burst length. Audio bit rate, packet-loss frequency, and average burst length are calculated from header information in received IP packets. For sampling rate, frame length, and audio codec type, the values or the names used in monitored services are input into this model directly. We performed a subjective listening test to examine the relationships between these input parameters and perceived audio quality. The codec used in this test was the Advanced Audio Codec—Low Complexity, which is one of the international standards for audio coding. On the basis of the test results, we developed an audio quality evaluation model. The verification results indicate that audio quality estimated by the proposed model has a high correlation with perceived audio quality.

Annual Report of Technical Committee on Information Networks

T. Tamura and J. Akiba

IEICE Communications Society GLOBAL NEWSLETTER, Vol. 32, No. 1, p. 5, 2010.

This document presents the annual report of the IEICE Technical Committee on Information Networks for activities from May 2009 to Mar. 2010.

Carrier's Perspectives for Future Transmission Systems and Networks

S. Matsuoka

Proc. of OECC2010, Vol. 6B2-1, pp. 40–41, Sapporo, Japan, July 2010.

This paper overviews future optical networks over the next few decades from the carrier viewpoint considering future advanced optical network technologies.

The Number Sense: How the Mind Creates Mathematics

S. Dehaene (author); M. Hasegawa and T. Kobayashi (translators), Hayakawa, 2010.

The Number Sense is an enlightening exploration of the mathematical mind. Describing experiments that show that human infants have a rudimentary number sense. Stanislas Dehaene suggests that this sense is as basic as our perception of color and that it is wired into the brain. Dehaene shows that it was the invention of symbolic systems of numerals that started us on the climb to higher mathematics. A fascinating look at the crossroads where numbers and neurons intersect. This book offers an intriguing tour of how the structure of the brain shapes our mathematical abilities and how our mathematics opens up a window on the human mind.

Phase Equalization-based Autoregressive Model of Speech Signals

S. Hiroya and T. Mochida

Proc. of Interspeech, ISCA, pp. 42–45, Makuhari, Chiba, Japan, Sept. 2010.

This paper presents a novel method for estimating a vocal-tract spectrum from speech signals, based on a modeling of excitation signals of voiced speech. A formulation of linear prediction coding with an impulse train is derived and applied to phase-equalized speech signals, which are converted from the original speech signals by phase equalization. Preliminary results show that the proposed method improves the robustness of the estimation of a vocal-tract spectrum and the quality of re-synthesized speech compared with the conventional method. This technique will be useful for speech coding, speech synthesis, and real-time speech conversion.

Design of Repetitive Knocking Force Display for Being Pulled Illusion

H. Hamaguchi, T. Amemiya, T. Maeda, and H. Ando

Proc. of RO-MAN, IEEE, pp. 33–37, Viareggio, Italy, Sept. 2010.

This paper discusses the design of a knocking force display to induce the kinesthetic illusion of being pulled. Previously, we have found that when a hand-held object oscillates in the hand, if the acceleration pattern is lopsided, one feels a pulling force sensation, although the object does move in two opposite directions. Here, we designed and developed a new force display to generate two imbalanced acceleration patterns in opposing directions. In the display, an internal mass repetitively collides against a wall, to create a spikier pulse than the previous force display could produce. We determined the circumstances under which the sensation of being pulled was perceived by varying the pulse width, i.e., by attaching materials of different stiffnesses to the wall.

A Sub-nanoampere Two-stage Power Management Circuit in 0.35-μm CMOS for Dust-size Batteryless Sensor Nodes

M. Ugajin, T. Shimamura, S. Mutoh, and M. Harada

Proc. of the 2010 International Conference on Solid State Devices and Materials, Vol. 42, No. 1, pp. 347–348, Tokyo, Japan, Sept. 2010.

A sub-nanoampere two-stage power management circuit that uses off-chip capacitors for energy accumulation is presented. Focusing on the leakage current and the transition time of the power switch transistor, we estimated the minimum current for accumulation. On the basis of the results, we devised a two-stage power management architecture for sub-nanoampere operation. The simulation and experimental results for the power management circuit describe the operation for a 1-nA current source.

Ultra-low Leak Regulator Circuits with SOI and Bulk Technologies Controlling Intermittent LSI Operation for Wireless Terminals in Wide Area Ubiquitous Network

M. Ugajin, A. Yamagishi, M. Harada, and Y. Kado

Proc. of the 2010 Asia-Pacific Radio Science Conference, Vol. 3, No. 1, p. D1-2, Toyama, Japan.

New low-leak regulator circuits for battery-equipped wireless terminals are presented. An SOI regulator circuit with a depletion-mode transistor can supply stable current with low battery voltage. A power switch using reversely biased bulk transistors has a very small leak current that is almost the same as that in SOI transistor switches. Measurements showed that battery-equipped wireless terminals with the proposed regulator circuits can operate for more than ten years.

A 16-Gbps Laser-diode Driver with Interwoven Peaking Inductors in 0.18-μm CMOS

T. Kuboki, Y. Ohtomo, A. Tsuchiya, K. Kishine, and H. Onodera

Proc. of the IEEE Custom Integrated Circuits Conference, Vol. 16, No. 5, pp. 569–572, San Jose, CA, USA, Sept. 2010.

A laser-diode (LD) driver with interwoven mutually coupled peaking inductors for high-speed optical networks is presented. Six and four inductors are interwoven into two sets of inductors for area-effective implementation as well as performance enhancement. The proposed circuit is fabricated in CMOS 0.18-μm process. The circuit area is 0.34 mm^2 and the maximum operating speed is 16 Gbps. Compared with a conventional LD driver in 0.18-μm CMOS, the proposed circuit achieves 1.6 times faster operation and 26% smaller area with 60% reduction in power consumption for the same amount of data transmission and LD driving current.

Report on 8th Asia-Pacific Symposium on Information and Telecommunication Technologies (APSITT 2010)

J. Akiba, N. Kamiyama, T. Tamura, S. Konno, H. Suzuki, K. Ueda, and T. Kawasaki

Proc. of the IEICE Communications Society GLOBAL NEWSLETTER, Vol. 33, No. 1, pp. 14–15, 2010.

This document describes the 8th Asia-Pacific Symposium on Information and Telecommunication Technologies (APSITT), held at Damai Beach Resort, one hour's drive north of Kuching, the capital of Sarawak, Malaysia, on June 15–18, 2010. This conference was sponsored by the IEICE Communications Society and organized by the Technical Committee on Information Networks and the Technical Committee on Network Systems.

Olfactory Display for Multi-sensory Theater

K. Hirota, Y. Ikei, and T. Amemiya

Proc. of ASIAGRAPH in Tokyo, Vol. 4, No. 2, pp. 24–28, Tokyo, Japan, Oct. 2010.

This paper describes an approach to implementing an olfactory display that is available in a multi-sensory theater environment for realistic presentation and communication. In our approach, the quantity of odorant emitted into the air, rather than its concentration, is controlled. Compressed air was used for quick emission of odorant, and magnetic valves were used to turn on and off the airflow. The quantity of emission was controlled by changing the duration of the discharge depending on the pressure of the air source; the relationship between the volume of emission and the duration time was analysed on the basis of experimental emissions, and the duration time for a given goal volume was computed by referring to the relationship. It was proved, through experiments using a prototype device, that this approach is feasible.

Confinement of Fluorescent Probes in Microwells on Si Substrates by Sealing with Lipid Bilayers

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We investigated the optimum architecture for confining fluorescent probes in microwells on a Si substrate by covering it with a lipid bilayer. We modified the structure of the wells to prevent the lipid membrane from falling into them, and the overhang shape at the aperture improved the probability of confinement. The fluorescence intensity from the calcein confined in the wells remained unchanged for one hour or more, indicating that the probes remain stably in the wells without flowing out. An artificial cell sealed with the suspended membrane is a promising tool for the functional analysis of membrane proteins.

An Innovative Rehabilitation Technique for Pipes Containing Cables

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As optical communication services expand, multiple cable installation has become usual in order to use the limited conduit space effectively. Approximately 3000 km of cables are multi-installed every year. However, more than half of the conduits scheduled for multiple cable installation were diagnosed as inappropriate (mainly owing to rust and corrosion) in preliminary inspections. Excavation-free inspection and renovation technologies for empty conduits have already been developed and used in practice. But because of the risk of damaging existing cables, there are no excavation-free renovation technologies for conduits that already contain cables. Therefore, we have developed cable-containing conduit renovation technologies that enable the repair of unsuitable occupied conduits without excavation and without affecting the cable within; moreover, these technologies maximize the accommodation capacity available after renovation. In this article, we outline the lining materials and renovation methods.

Correction Factors for Field Singularity at 45° Corners in the Finite-difference Analysis of Microstrip Circuits

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In microstrip circuits, the field concentrates at the edges and corners of a thin strip conductor. This yields rapid variation in field strength with its position in their proximity, which might cause a significant error in the finite-difference approximation of the field analysis. The accuracy may be improved by using finer discretization. However, refining the grid in three-dimensional space will soon require huge computational resources. It would be beneficial to improve the accuracy without greatly increasing the analysis cost. To this end, a modification of the finite-difference formulation for the local field singularity was proposed previously. This paper presents correction factors for 45° corners of thin metal plate used for the modification and examines the accuracy improvement in the analysis of microstrip structure.
