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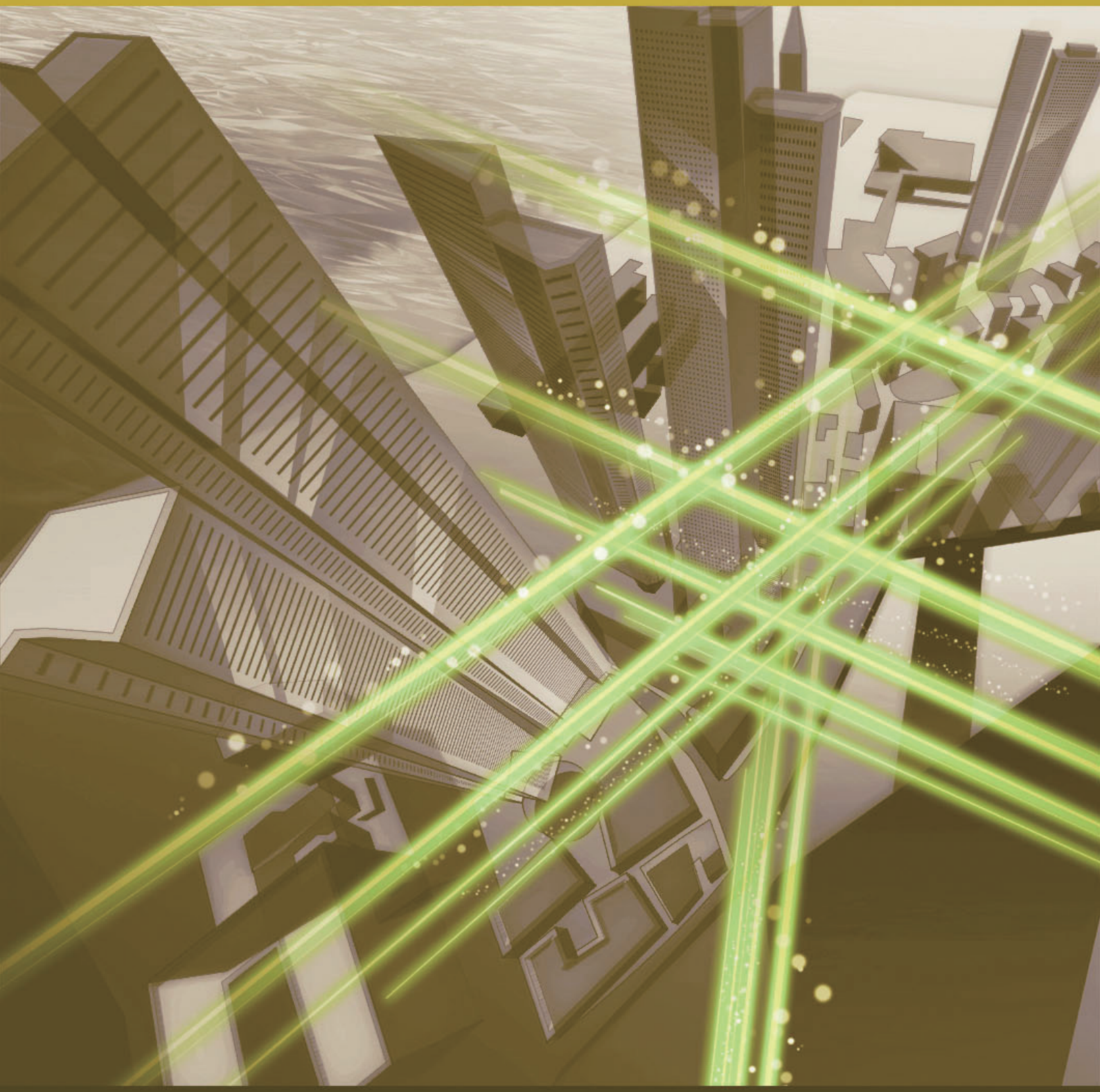

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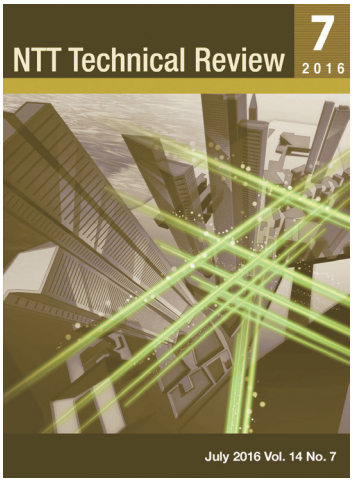

Feature Articles: NTT Group Activities in the Transportation Field

NTT Group Activities in Transportation × ICT

Joint Experiment on Enhancement of Information Universal Design at Airports

Seamless Indoor/Outdoor Navigation Feasibility Test near Tokyo Station—Part of the High-Accuracy Positioning Society Project Sponsored by the Ministry of Land, Infrastructure, Transport and Tourism

Development of Map Platform Technology to Innovate Seamless Navigation

Technology for Social Development of Accessibility Maps

Development of a Mobile Personal Agent that Expands Human Potential

Agile Development of JR East App Designed to Enhance Customer Service Quality

Regular Articles

Pitarie: Picture Book Search with Interdisciplinary Approach

Move&Flick: Text Input Application for Visually Impaired People—From Research and Development to Distribution of the Application

Global Standardization Activities

G.fast Ultrafast Access Technology Standardization in ITU-T

Global Activities of NTT Group

NTT Communications Corp.—Acquisition of Virtela and Provision of Arcstar Global Network Services

Practical Field Information about Telecommunication Technologies

Improvements in Cable Surge Protectors

External Awards/Papers Published in Technical Journals and Conference Proceedings

External Awards/Papers Published in Technical Journals and Conference Proceedings

NTT Group Activities in Transportation × ICT

Satoshi Fukada and Kazunari Moriuchi

Abstract

The NTT Group is promoting collaboration with partners in fields where information and communication technology will be further exploited. The Feature Articles in this issue introduce our collaborations with members of the transportation industry and the technologies being applied in these collaborations.

Keywords: transportation, seamless, diversity

1. Introduction

In January 2016, CES (Consumer Electronics Show) 2016, the world's largest home appliance exhibition for consumers, was held in Las Vegas. This annual event is sponsored by the Consumer Electronics Association. Whereas CES's main focus had conventionally been on television and audio/visual appliances, in recent years the spotlight has been shifting to devices that are connected to networks such as wearable devices and sensors (i.e., Internet of Things (IoT)). While this trend is ongoing, CES 2016 also saw many mobility-related exhibits such as vehicle-related devices and drones. For example, one exhibit demonstrated how vehicles that had bumped against each other learned to avoid collisions and yield the right-of-way to each other. This seems to point to a future world in which a variety of moving objects become intelligent through being connected to a network and thereby learn to optimize their behavior.

In Japan, the population aging ratio (ratio of those aged 65 or older to the entire population) was under 10% in 1980, but by October 2014, it had soared to 26%, and it is expected to exceed 30% by 2025 [1]. In such a super-aging society, there is a pressing need to exploit information and communication technology (ICT) and software infrastructure in addition to strengthen the hardware infrastructure in order to support the formation of the *super-mega-region* and the development of compact cities and the related connectivity innovation [2].

The number of visitors to Japan from abroad has been increasing dramatically year by year, reaching 19.73 million in 2015 [3]. In response, the government raised its target for the annual number of international visitors by 2020 from 20 million to 40 million. Since such an explosive increase in overseas visitor numbers will give rise to congestion in transportation systems and tourist spots, there is an urgent need to reinforce the country's hardware and software environments in order to welcome these visitors.

As the environment surrounding transportation changes, new technologies have been developed, but various issues have also arisen.

2. NTT Group activities in transportation × ICT

The role of information and communication providers is changing. The NTT Group regards ICT as a catalyst for such change and seeks to enhance the value of various fields and industries. We have selected strategic target fields including transportation, agriculture, medical care, urban development, and tourism. In the transportation field, the group is pressing ahead with activities to further exploit ICT (transportation × ICT).

Among the group's transportation × ICT activities, this article focuses on achieving *diversity navigation* [4], which targets people in motion in light of the super-aging society and the increasing number of international visitors, and optimizes people's mobility by seamlessly connecting various means of

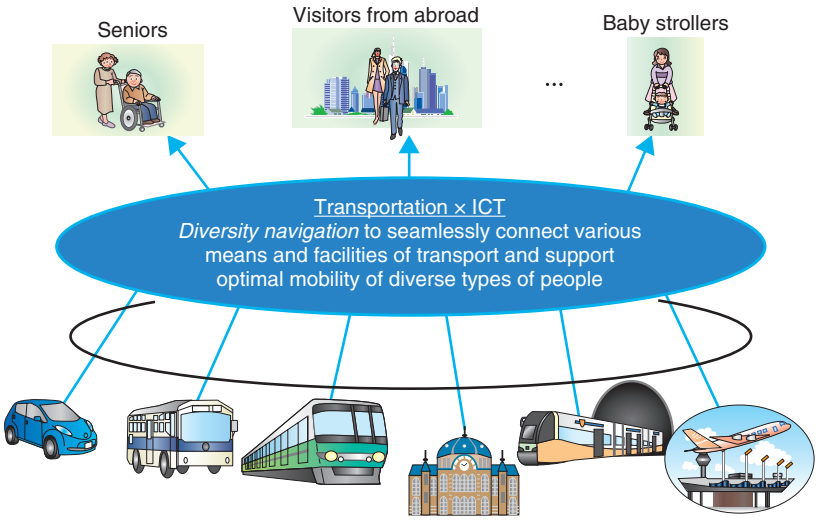

Fig. 1. Direction of transportation × ICT.

transportation and mobility (**Fig. 1**).

3. Seamless transportation

When people move from point A to point B, they use a combination of different means of transportation. They may walk, drive their own cars, take a bus, taxi, train, or airplane, or go sightseeing in a personal mobility vehicle or on a shared bicycle. Advances in the means of transportation are making it increasingly difficult to determine the best combination. This issue is particularly serious for seniors and visitors from abroad. Beyond the obvious language problems, it is difficult to determine where the required information can be found. The degree of detail and the means of information presentation vary from one transportation provider to another. There are no links between items of information that different providers offer. The manner of representing transportation facilities (e.g., train stations) on maps varies from facility to facility, and maps are not connected to one other. Taken together, these discrepancies constitute a substantial barrier to mobility. Consequently, we believe that it is extremely important to make the various means of transportation, information about facilities offered by transportation providers, and transportation services seamless through the power of ICT.

4. Diversity navigation

It is not only seniors and international visitors who encounter mobility barriers. So, too, do pregnant women, small children, injured persons, people carrying heavy baggage, and those who are physically impaired (handicapped in respect of mobility, vision, hearing, etc.). The needs of these people are so diverse that it is not always possible to meet them solely with equipment, appliances, physical assistance, or hospitable behavior. It is necessary to use ICT to assist these people, in addition to making transportation seamless.

For example, when it comes to serving overseas visitors, it is difficult to have direction signs at stations provide information in over 100 languages, or for station employees to speak as many languages. It will be effective to provide multi-lingual support using ICT. We call the presentation of information adapted to diverse human needs and optimal mobility support diversity navigation, and we are developing relevant technologies and promoting the provision of relevant services.

5. Applied technologies

What kinds of technologies are required to achieve seamless transportation and diversity navigation (**Fig. 2**)? First, seamless digital maps are needed in order to sort out various items of information needed for mobility. The more diverse and sophisticated the movements of people and objects become, the higher the degree of accuracy required of digital maps for use in navigation and control. Furthermore, in order to be able to provide navigation and control that are

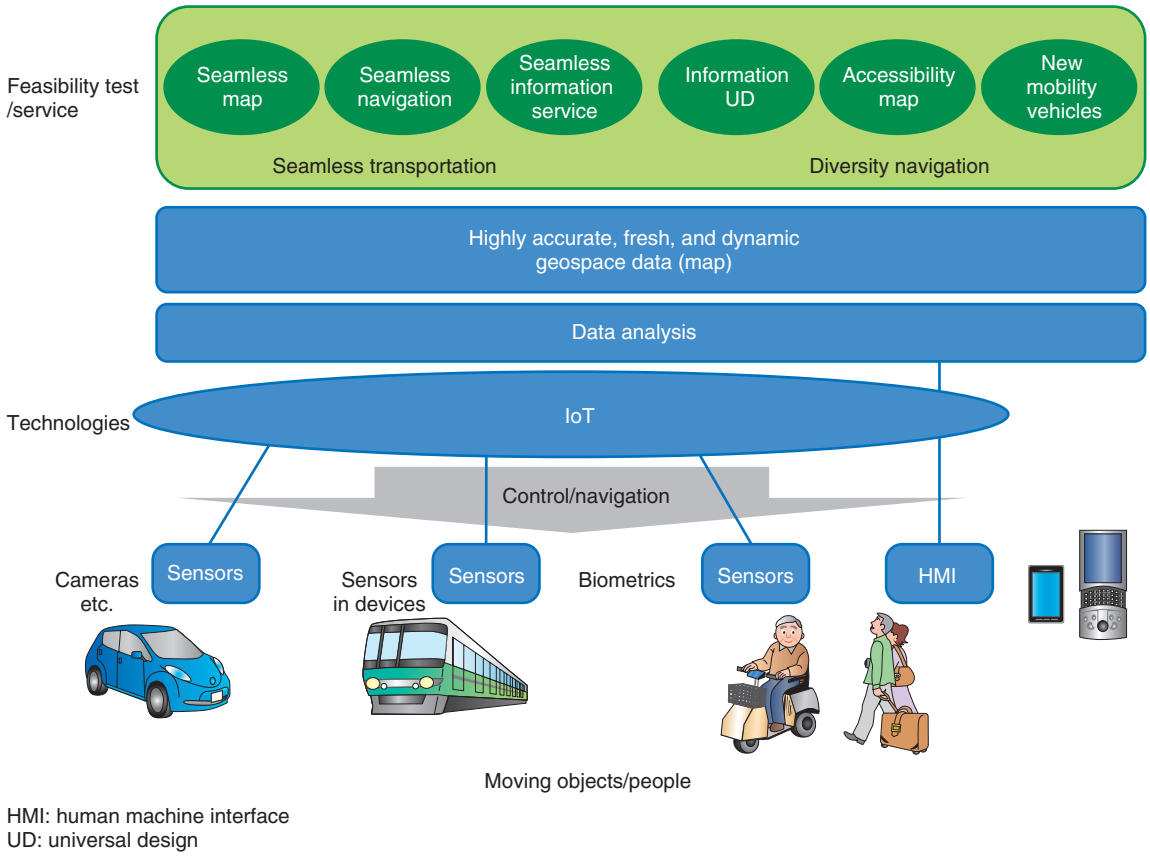

Fig. 2. Technologies that support transportation × ICT and feasibility tests/services.

optimal for the moment, we need fresh (up-to-date), dynamically changing information for the relevant place. It would be more appropriate to call such information *geospace data* rather than a map.

Next, in order to be able to dynamically add information to geospace data, we need sensors that monitor people and their environments, a network for collecting sensor data (IoT), and data analysis technology that understands and predicts people's intentions, situations, and environment from the collected sensor data. Here, sensors include positioning mechanisms to pinpoint locations, which are important for mobility, in addition to those that monitor biometrics, cameras, and device sensors.

Then, in order to be able to provide information and navigation that are appropriate for the particular person or situation, the human machine interface (HMI) is important. To provide a better HMI, we are upgrading various technologies such as smartphones, digital signage, virtual reality, audio, and vibration technologies, and studying optimal combinations of these.

6. Feasibility tests

In parallel with the above-mentioned technological development, the NTT Group is carrying out feasibility tests and providing new services in collaboration with partners in the transportation field. We are participating in the Seamless Indoor/Outdoor Navigation Feasibility Test near Tokyo Station [5] and developing advanced technologies in this area in order to achieve seamless transportation [6]. We are developing seamless information services to be provided on trains and at stations [7] and are conducting a joint experiment to upgrade the universal design of information at Haneda Airport [8]. We are also developing technologies for creating accessibility maps with citizen participation and have carried out experiments on these technologies [9]. We recently ran a feasibility test of a personal agent designed to achieve a new type of mobility [10].

7. Toward mobility as a service

It is being projected that self-driving vehicles will become a reality in the 2020s. When vehicles and other objects that move about become extremely sophisticated, what will the whole transportation system be like? Some people suggest that vehicles will become more autonomous as they become self-driving, and that the sharing economy, represented by ride sharing, will penetrate society [11]. This trend would appear to indicate that transportation systems will soon become a seamless service. In such a world, all means of transportation will be connected seamlessly and will be controlled in a globally optimal manner. People will be able to use diverse means of transportation at will, whenever and to whatever extent they require. In October 2015, the Mobility as a Service Alliance initiative [12] was established in Europe. This is certainly aimed at that type of world.

In light of this trend, the NTT Group, building on the strength of having seamlessly connected and operated networks of world-wide telecommunications providers, will accelerate collaboration with transportation-related partners and thereby contribute to the development of the transportation field.

The Feature Articles in this issue introduce the technologies that support the NTT Group's activities on transportation × ICT, feasibility tests of transportation-related facilities centering on support for pedestrian mobility, and activities on transportation-related services that are being commercially provided.

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Satoshi Fukada
Senior Manager, Transport and Mobility Business Producer, Strategic Business Creation Team, NTT Research and Development Planning Department.

Kazunari Moriuchi
Chief Producer, Growth Hacker, Strategic Business Creation Team, NTT Research and Development Planning Department.

Joint Experiment on Enhancement of Information Universal Design at Airports

Yusaku Kuhara, Shinichiro Yamashita, Shingo Kinoshita, Hirohisa Tezuka, Yusuke Ichikawa, and Satoshi Fukada

Abstract

It is necessary to further improve barrier-free mobility and accessibility to information at international airports, which serve as gateways for visitors from abroad. Of course, airports also provide opportunities to publicize Japan's cutting-edge technologies to the world. This article introduces a joint experiment conducted at Haneda Airport by NTT and Tokyo International Air Terminal Corporation with a view to enhancing information universal design in air terminals.

Keywords: airport, information universal design, accessibility

1. Introduction

The Haneda Airport International Passenger Terminal (hereinafter "international terminal") has adopted user-participation type universal design since the design stage. The universal design for this international terminal is top-notch from both hardware and software perspectives. Universal design is socially integrated with human diversity. With the rapid increase in the number of international visitors to Japan and the dramatic growth in the number of international flights in recent years, the current hardware and software capacities of the terminal are expected to be exceeded in the near future. Further efforts are therefore required in order to provide multilingual services and reduce congestion. Since its inception, Haneda Airport's Universal Design Study Committee has studied and implemented improvements in the international terminal every two years. In the latest meeting of the committee, some members urged further utilization of information and communication technology (ICT) because it is difficult to resolve issues through the conventional means of fixed information boards and face-to-face provision of guidance. A new generation of ICT techniques is required in order to improve accessibility and enhance customer experience.

2. Joint experiment to enhance information universal design at airports

In light of the above conditions at Haneda Airport, the world's first joint experiment to enhance information universal design was carried out in Haneda's international terminal from December 2015 through March 2016, using cutting edge information technologies encompassing sound, light, images, and wireless communication. The experiment was aimed at improving accessibility for overseas visitors and generally enhancing universal design, with a particular focus on assisting international visitors, wheelchair and baby stroller users, and seniors to enjoy better mobility both within and out of the terminal.

3. NTT's feasibility test

In view of the needs to 1) support multiple languages and cultures, 2) optimize guidance for easy mobility, and 3) support seniors and persons with disabilities in airports, train stations, streets, and public

areas such as stadiums as we approach 2020, NTT believes that it is necessary to adopt ICT solutions in addition to the conventional physical measures. To this end, NTT has been studying the provision of innovative hospitable user interface (UI) and user experience (UX) by exploiting cutting-edge technologies such as sound, image analysis, and big data analysis. As part of the joint experiment, NTT carried out a feasibility test at Haneda Airport in an effort to resolve the above-mentioned issues. Specifically, the following three experiments were conducted to evaluate the effectiveness of the technologies used to enhance information universal design and to identify issues to be addressed before these services are actually introduced.

4. Information provision through *pointing UI* made possible using image processing technology

We developed a UI that involves pointing actions to help visitors find the information they need. We describe here the UI and the technical issues involved.

4.1 Problems

For visitors from abroad, linguistic and cultural differences relating to mobility and food services in strange places can be very stressful. In particular, in an airport, which is the first place they experience on arrival, they may encounter a number of problems. For example, they may find that most information boards are written only in Japanese, English, and one or two other major languages. Also, they might hesitate to go inside a shop or restaurant because they cannot imagine what the shop or restaurant is like, or they cannot easily find any way of checking the ingredients of Japanese dishes with which they are not familiar.

4.2 Overview of experiment

In light of these issues, NTT has been developing technology that enables users to easily obtain useful information through only intuitive actions. NTT has developed angle-free object search technology [1] that offers a UX in which the user can obtain appropriate and useful information by simply pointing the camera of his/her smartphone at a sign/information board in the arrival hall, or at shops, food dish samples, or products in the commercial area of the air terminal. The objectives of this experiment were to evaluate the effectiveness of this UX and to identify issues to be addressed in order to improve image recognition accuracy in real fields, and issues related to commercial service introduction (**Photo 1**).

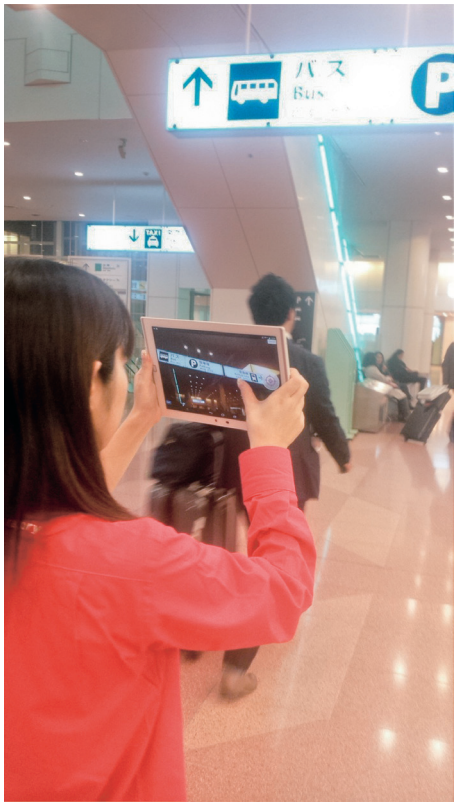

Photo 1. Pointing UI using image analysis technology.

In fiscal year 2015, we conducted a field survey on information needs at airports with users from abroad (English or Chinese speakers). We asked when and where respondents had experienced information accessibility problems, what kinds of information they were seeking, what means of information search they used, and the extent to which they obtained information in each of the following five categories: transportation, telecommunications, food, shopping, and others. The objective was to obtain quantitative data on needs and find some use cases for utilization in our future service design work.

In addition, we asked respondents to actually try the pointing UI in order to obtain data about how they pointed their smartphones at objects (what actions they took to point their smartphones and from what angles objects were photographed). Since the current design of the UX of the pointing UI is based on the typical pointing actions of Japanese users, we plan to use the obtained data when we design the UX of applications that are intended for visitors from abroad (**Photo 2**).

Photo 2. Real field survey of the pointing UI.

4.3 Technical points

Angle-free object search technology automatically recognizes an object from an image captured by a camera. When one or just a few photos of an object are taken from the front and from oblique angles and registered in a database in advance, this technology can recognize the object from a photo with a high degree of accuracy, even if it has been photographed from a different angle, or even if parts of the object are hidden. One advantage of this technology is that it can be implemented at low cost because it requires no installation work in the surrounding facilities.

5. Guidance of pedestrian flow using dynamic signs based on big data analysis

Another area we wanted to improve was how pedestrians are guided in public areas.

5.1 Problems

The number of visitors from abroad has been increasing every year, exceeding 16 million as of October 2015 [2]. As a result, the congestion at airports is continuing to increase. There is an urgent need to solve this problem.

5.2 Overview of experiment

NTT is studying a way to optimally guide pedestrian flow to help people avoid congested areas by foreseeing future degrees of the constantly changing congestion state and dynamically altering direction signs accordingly. NTT will trial a dynamic display of direction signs in places where people tend to congregate such as the departure hall or passport control area in order to identify the best ways of presenting information (notations, color, timing, etc.) and also to verify the effectiveness of presenting information visually for hearing-impaired persons in cases where only audio announcements have conventionally been made, such as in cases of emergency.

In fiscal year 2015, we trialed a display of direction signs using projection mapping and observed congestion states in two use cases: in the arrival hall on the second floor and in the passport control area in the departure hall on the third floor (**Photo 3**). In this trial, we developed a hypothesis for congestion

Photo 3. Direction sign using projection mapping.

reduction from observing people's behavior. On the basis of the hypothesis, we designed signs that reflected universal design and evaluated the effectiveness of the information and direction signs, both qualitatively and quantitatively, by projecting these signs in the real field.

For the qualitative evaluation in the real field, we used three representation patterns: 1) superimposing information in a manner similar to augmented reality, which was aimed at enhancing visual attraction, 2) projecting animation of existing pictorial signs, which was aimed at enhancing visual attraction and increasing the volume of information that can be presented, and 3) simply projecting still images of existing signs. We identified issues regarding the formulation of a universal design standard by interviewing more than 100 domestic and international (English or Chinese speaking) visitors to get their evaluations of the above signs from four aspects: visual attractiveness, visibility, understandability, and stimulus for behavior change.

For the qualitative evaluation, we measured the effect of the guidance using dynamic sign projection on pedestrian flow by counting the number of people who passed through and the number who stayed (number of people in queues, etc.) in respective places for a case where projection mapping was employed and for a case where it was not. The results obtained will be used as parameters in ongoing simulations.

5.3 Technical points

We aim to achieve a proactive form of guidance using new dynamic signs in order to predict potential congestion and to prevent it from occurring. This guidance combines the pedestrian flow simulation using the spatio-temporal multidimensional collective data analysis technology [3] being developed by NTT and projection mapping, which allows flexible projection of information.

6. Intelligibility enhancement sound signs using voice processing technology

We are also exploring the use of ICT to assist visually impaired people. The premise of the system is

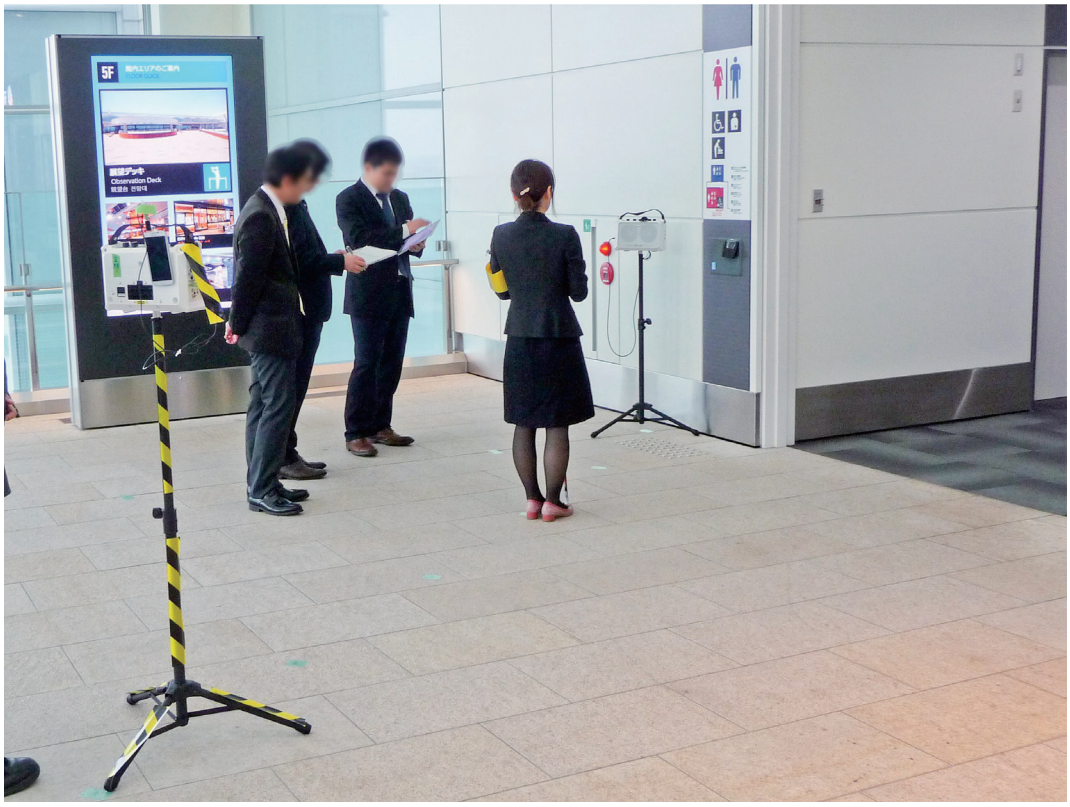

Photo 4. Scene of experiment to test speech intelligibility enhancement.

explained here.

6.1 Problems

Airports and train stations support the mobility of visually impaired people by providing information using systems designed for senses other than sight. A typical example is a *sound sign* that provides voice guidance to assist people in restrooms or on escalators, as well as acoustic guidance in other places. Sound signs are provided in accordance with the barrier-free environment guidelines developed by the Ministry of Land, Infrastructure, Transport and Tourism. Although they are very useful, they are not sufficiently widespread because of physical restrictions or high ambient noise levels in potential installation sites.

6.2 Overview of experiments

The intelligent sound sign proposed by NTT has two features. One is that it uses a speech intelligibility enhancement technique to provide guidance even under ambient noise. The other feature is that it switches to the user's mother tongue when the user approaches places where the guidance is needed. It utilizes voice guidance devices, access points, beacons, and the user's smartphone. With this system, we intend to realize a society in which the visually impaired can more easily utilize public facilities such as airports and train stations.

In fiscal year 2015, we conducted experiments with the participation of visually impaired subjects. In test environments that replicated the background sounds often heard at an airport (e.g., the sounds of suitcases being rolled), the subjects heard a voice guidance message produced using the synthesized speech intelligibility enhancement technology [4] developed by NTT as well as a guidance message conveyed using the conventional sound sign approach. We compared the subjects' comprehension levels for the respective sound sources in terms of how well the speech was conveyed (standing next to the sound source) and how the distance from the sound source affected comprehension (standing some distance from the sound source) (**Photo 4**).

The system we developed and experimentally evaluated in fiscal year 2015 is a sound sign system

Photo 5. Scene of experiment to test usability.

that works with voice guidance devices, commercial smart watches, and smartphones. The experiment was conducted with visually impaired subjects to evaluate the system's usability. In this experiment, guidance to a restroom at the airport was taken as the use case. We evaluated the system's effectiveness for mobility support and identified issues to be addressed prior to commercial introduction (**Photo 5**).

6.3 Technical points

The speech intelligibility enhancement technique measures ambient sounds and adjusts the tonal characteristics of the voice relative to that of the background sounds so as to emphasize speech clarity. Therefore, voice guidance can be heard clearly, even in noisy surroundings.

7. Future development

NTT and Tokyo International Air Terminal Corporation are working on improving information universal design by participating in the Committee to Study Information UD (universal design) at Airports (Chair: Professor Tetsuo Akiyama, Chuo University), established in November 2015. On the basis of the results of the joint feasibility test described in this article, we will develop and introduce the technologies outlined here and also develop new technologies as we approach 2020. We will also invite other airports and enterprises to participate in joint experiments as new partners.

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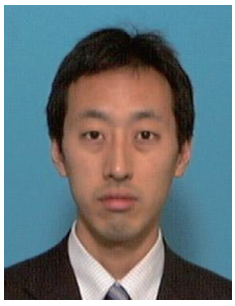
Shingo Kinoshita
Senior Manager, NTT Service Evolution Laboratories.

He received a B.E. in solid state physics engineering from Osaka University in 1991 and an M.Sc. with Distinction in technology management from University College London, UK. Since joining NTT laboratories in 1991, he has been engaged in research and development (R&D) of distributed computing systems, security, big data computing, and human resources of the laboratories. He helped establish NTT Innovation Institute, Inc. in North America and also helps manage it. Some of his other responsibilities include planning and managing NTT laboratories, supporting NTT's chief technology officer, and heading the Dwango-NTT capital and R&D alliance. He has published more than 30 journal and international conference papers. He received the 2005 IPSJ R&D Award from the Information Processing Society of Japan (IPSJ), the 2003 CSS (Computer Security Symposium) Best Paper Award, and the 1998 DICOMO Best Presentation Award.

Hirohisa Tezuka
Senior Research Engineer, Supervisor, 2020 Epoch-making Project, NTT Service Evolution Laboratories.

He received a B.E. and M.E. in engineering from Kyoto University in 1991 and 1993. He joined NTT in 1993. His research interests include system management, networked robotics, and lifelog systems. He is a member of the Society of Instrument and Control Engineers.



Yusuke Ichikawa
Senior Research Engineer, 2020 Epoch-making Project, NTT Service Evolution Laboratories.

He received a B.E. and M.E. in measurement engineering from Keio University, Kanagawa, in 1995 and 1997. He joined NTT Multimedia Network Laboratories in 1997. Since 1998, he has been engaged in R&D of recommendation systems. He is a senior member of IPSJ and received the 2005 IPSJ Yamashita SIG Research Award.

Satoshi Fukada
Senior Manager, Transport and Mobility Business Producer, Strategic Business Creation Team, NTT Research and Development Planning Department.

*Yusaku Kuhara and Shinichiro Yamashita are with Tokyo International Air Terminal Corporation.

Seamless Indoor/Outdoor Navigation Feasibility Test near Tokyo Station—Part of the High-Accuracy Positioning Society Project Sponsored by the Ministry of Land, Infrastructure, Transport and Tourism

Naoki Iso and Yoichiro Takaki

Abstract

Outdoor positioning accuracy will improve when full-fledged operation of the quasi-zenith satellite system starts in 2018. This, together with advances in indoor positioning technology, is expected to usher in a high-accuracy positioning society, in which high-accuracy location information can be used seamlessly both indoors and outdoors. This article introduces the Seamless Indoor/Outdoor Navigation Feasibility Test near Tokyo Station, conducted as part of the *High-Accuracy Positioning Society Project* sponsored by the Ministry of Land, Infrastructure, Transport and Tourism.

NTT DATA and NTT GEOSPACE were selected to participate in the *Realization of a High-Accuracy Positioning Society* study, an initiative adopted by the National Land Information Division of the Ministry. This article reports on the activities of these two companies in the feasibility test.

Keywords: geospace, high-accuracy positioning society, seamless indoor/outdoor positioning

1. Introduction

Full-fledged operation of four quasi-zenith satellites will start in 2018. This will dramatically enhance the high-accuracy positioning environment, providing opportunities to create new services across a wide range of fields, including disaster prevention, transportation, and agriculture, as we approach 2020. Activities have been carried out in the past to improve positioning accuracy in indoor areas, where positioning satellites are ineffective. However, various obstacles have stood in the way of building positioning environments that can be used in a wide variety of areas. Since many people spend much of their time indoors in places such as underground shopping arcades, other commercial facilities, and office buildings, a positioning environment that can seamlessly work both indoors and outdoors is desirable. Establishment of such environments will give rise to a variety of location information-based services. It will also provide convenience, safety, and security for tourists and international visitors, and help to resolve social issues related to indoor spaces.

The National Land Information Division, which is part of the National and Regional Policy Bureau in the Ministry of Land, Infrastructure, Transport and Tourism, is undertaking the High-Accuracy Positioning Society Project with a view to building a world-leading environment that will facilitate the creation of services that utilize indoor/outdoor positioning

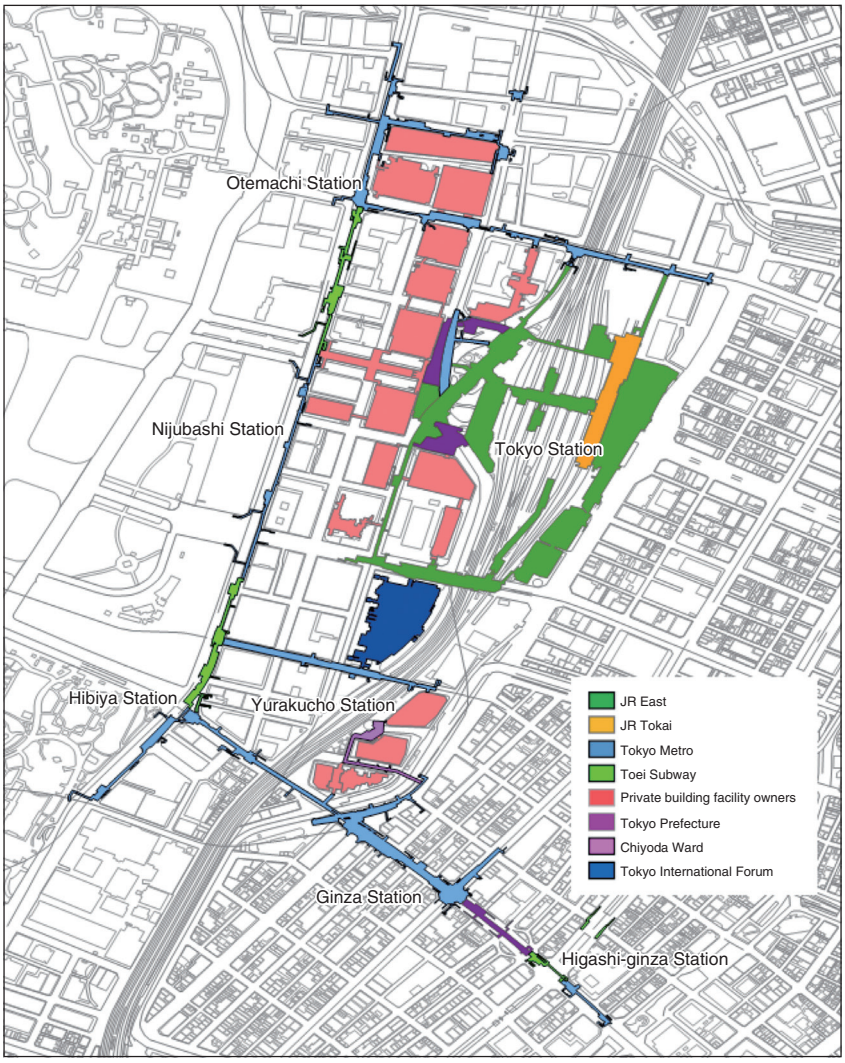


Fig. 1. Area (underground space) covered by the feasibility test.

technologies.

This article introduces the Seamless Indoor/Outdoor Navigation Feasibility Test near Tokyo Station, which was conducted as part of this project in fiscal 2015. The test is focused on developing a seamless indoor/outdoor digital map, constructing a positioning environment, developing a navigation application that uses this environment, and implementing service ideas that have emerged.

2. Overview of feasibility test

In fiscal 2014, a number of enterprises participated in the High-Accuracy Positioning Society Project, in which an experiment was carried out to evaluate the accuracy and effectiveness of various positioning methods in a small area near Tokyo Station. Based on the results of that experiment, a larger-scale feasibility test was conducted for a period of about one month (February 4 through March 6, 2016) in a larger area (encompassing the Otemachi, Marunouchi, Yurakucho, Yaesu, and Ginza districts) that is criss-crossed by underground passageways near Tokyo Station (**Fig. 1**). A trial navigation service was provided in this test, using an application called Japan Smart Navi. In preparation for this trial, a digital indoor map of the area was developed, and an environment for an indoor positioning service was built by installing indoor positioning devices. In parallel with the trial, activities were carried out to expand the

use of location information services that would work in this seamless indoor/outdoor positioning environment. Those activities included feasibility tests of various applications provided by companies that have business ideas, and an ideathon/hackathon that was conducted to encourage the generation of ideas on location information-assisted applications that would enhance the appeal of Tokyo Station.

2.1 Objectives of feasibility test

The objectives of the feasibility test were to identify new technical and operational issues by extending the trial area from a limited area to a wider area covering an extensive network of underground shopping arcades, and to develop a model business operation that could be emulated elsewhere. The environment for a location information-based service was constructed at low cost using off-the-shelf technologies based on the reasoning that the positioning accuracy only needed to be adequate for pedestrian navigation. This would make it financially possible for organizations elsewhere to construct similar environments. All of the preparatory work for the feasibility test was studied and recorded, including both operational procedures—such as obtaining facility drawings, negotiating with owners of buildings and underground shopping arcades regarding installation of positioning devices, and applying to government offices for permission to use underground and other spaces—and technical procedures such as studying optimal locations for beacons and developing an integrated indoor map.

2.2 Feasibility test environment

(1) Digital indoor map

It was decided to efficiently develop an integrated digital indoor map by using existing maps and measurement records as much as possible instead of initiating a new survey, considering that the map only had to be adequate for pedestrian navigation. Key considerations in developing the digital map were as follows:

- NTT GEOSPACE's "GEOSPACE" map, which includes corrections to the reference map, was used as the reference outdoor map.
- Existing mobile mapping system data were also used at the connection points between indoor and outdoor maps.
- Location information codes were assigned to anchor points at which indoor and outdoor maps had to be interconnected seamlessly.
- The map was developed so as to conform to the draft map specifications being studied by the Geospatial Information Authority of Japan.

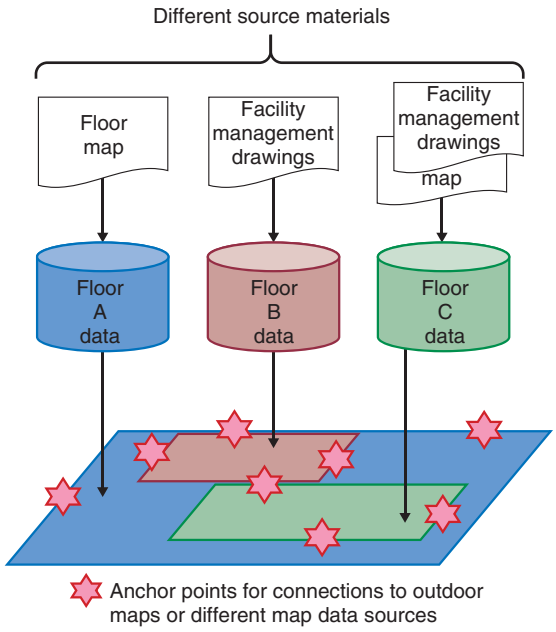


Fig. 2. Map production flow.

For indoor spaces in buildings and underground shopping arcades, floor plans and facility drawings held by respective facility owners were collected. Anchor points were specified at interconnections between indoor and outdoor areas and at entrances to buildings and underground pathways (**Fig. 2**). To develop a single map from multiple drawings, it was necessary to connect different drawings seamlessly. Therefore, the bulk of the map development work involved making adjustments at interconnection points between different drawings and between indoor drawings and outdoor maps. Since our target map was to be made public, we had to extract from facility drawings those areas where pedestrians would pass through. These facility drawings were essential in developing a precise digital map, so care was taken to collect them efficiently and securely.

(2) Positioning environment

We planned and constructed the positioning environment in such a way that it would best support pedestrian navigation. The main considerations in planning the environment were as follows:

- Inexpensive beacons for transmitting positioning signals were installed. We utilized NTT DATA's know-how gained through its BeaconNAVI.
- Beacons were installed at high density in some

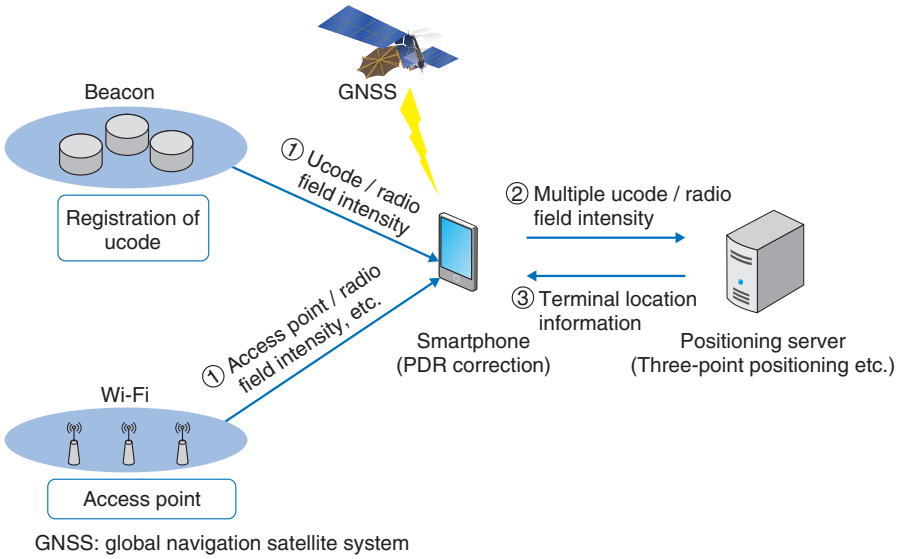


Fig. 3. Configuration of feasibility test system.

areas and low density in other areas, depending on the availability of existing Wi-Fi signals.
- A location information code based on ucode was transmitted so that the location could be identified without having to send an inquiry to a server.
- Pedestrian dead reckoning (PDR) was used as a means of positioning that did not depend on signals.

BeaconNAVI is a mechanism in which the installation of beacons at 10 m intervals enables a positioning resolution of 3 m and enables the switching of floors (i.e., selection of floors) in a commercial facility with an atrium. We installed the bare minimum number of beacons to provide a positioning resolution that was adequate for pedestrian navigation. Some 300 beacons, most of them battery powered, were installed. We had to install solar-powered beacons, which do not require frequent maintenance, in some areas where it was necessary to reduce the workload of replacing batteries.

(3) Feasibility test system and application

We provided a navigation service using Japan Smart Navi, a prototype application that used the established positioning environment and map, in the hope that many people would appreciate the convenience of seamless indoor/outdoor navigation. The configuration of the feasibility test system is shown in **Fig. 3**.
- Positioning module: This module obtained information about beacons and Wi-Fi access points from the server. If it could not receive any positioning signals, it used PDR to calculate the best location estimate using a number of positioning methods.
- Map information display: Map information was displayed for each floor (story). The map was scrolled, and the floors were switched based on location information.

We provided information about points of interest (POIs) including public areas—such as ticket gates at stations, exits at the ground level, and restrooms—and private-sector POIs such as restaurants, information for which was managed by NTT Resonant, the provider of the "goo!" portal site. The main functions of the application are:
- Searching for a particular place, focusing on POIs near Tokyo Station
- Search for a route that indicates the optimal route to the destination or a route with fewer barriers
- Displaying the current location, provided seamlessly whether indoors or outdoors

In addition to the application provided by the feasibility test organizer, the positioning environment and the map were provided independently in order to encourage creation of services by third parties. We collaborated with four enterprises/organizations to test their applications, which were aimed at supporting stress-free mobility, providing safe evacuation guidance in times of emergency, or enhancing positioning accuracy.

Fig. 4. Scenes from the ideathon and hackathon.

3. Ideathon and hackathon

We surmised that the availability of the positioning environment and the indoor map would encourage the creation of new services, so we conducted an ideathon on December 13, 2015 and a hackathon on January 23–24, 2016 entitled Ideathon/Hackathon to Enhance the Appeal of Tokyo Station (**Fig. 4**). These events were coordinated by Associate Professor Naohiko Kohtake of the Graduate School of System Design and Management at Keio University.

The participants were highly motivated since these events concerned the area around Tokyo Station, which has symbolic significance. Consequently, 11 service ideas were presented in the ideathon. It was confirmed that in addition to services proposed by enterprises/organizations, efforts to invite members of the general public to propose service ideas were effective for creating a variety of location information-based services.

In the hackathon, six teams developed service prototypes based on the service ideas presented in the ideathon within a limited period. To enable quick development, we helped by providing positioning modules and map information, and organizing a support team that assisted the contestants in data collection and service development. As a result, innovative and/or highly feasible services were developed such as a tour guide around Tokyo Station using bots (software agents) and mission-clear type information collection associated with location information. Thus, the establishment of a seamless indoor/outdoor positioning environment and map led to the creation of a range of services.

4. Future prospects

Japan has a number of terminal stations with large underground spaces for pathways and commercial activities. Establishing a seamless indoor positioning environment and map in such places will enable the creation of new, world-leading services.

To expand the number of indoor areas where positioning environments are available, it is necessary to solve both operational issues—such as how to efficiently collect facility design drawings for producing an indoor map and how to reduce the workload of installing and maintaining positioning devices—and technical issues such as how to produce a seamless map and how to improve indoor positioning accuracy.

Improvement in positioning accuracy is expected to lead to the development of barrier-free applications and to facilitate risk management and infrastructure management. Combining positioning capability with information and communication technology will stimulate development of real-time information services with high added value that will work with digital signage units that are associated with location information. It will also make it possible to analyze the data of collected location-related information in order to resolve congestion at event sites or provide smooth evacuation guidance during emergencies. As we approach 2020, high-accuracy positioning is expected to improve services across a wide range of fields such as improving convenience for tourists and international visitors, and assisting in transportation planning and personnel distribution planning.

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Naoki Iso

Senior Manager, Sales and Marketing Group 3, e-Community Division, Public Sector 1, NTT DATA Corporation.

He joined NTT DATA Communications Systems Corporation (now NTT DATA Corporation) in 1995. Since then, he has been engaged in planning and development of products that utilize geographic information systems and earth observation satellite. Since taking up his current position in 2014, he has been promoting the Geospatial project, including location-based services.

Yoichiro Takaki

Senior Vice President, Executive Manager, Business Development Department, NTT GEOSPACE CORPORATION.

He received a B.E. in civil engineering from Osaka Institute of Technology in 1986 and joined NTT the same year. He was mainly engaged in the planning of outdoor plants for telecommunication networks and the development of operation systems. Since July 2008, he has worked on a project to develop geographic information systems. He has also been engaged in business development for the geographic information industry since July 2011. He is currently with NTT GEOSPACE.

Development of Map Platform Technology to Innovate Seamless Navigation

Hirofumi Abe, Shunsuke Konagai, Shigeru Chiba, Makoto Muto, Mitsutoshi Nagahama, Hitoshi Seshimo, Akihisa Kawanobe, Yoshimasa Koike, and Satoshi Fukada

Abstract

The introduction of four quasi-zenith satellites (in 2018) and advances in indoor positioning technology are expected to usher in a high-accuracy positioning society by 2020. Under such a high-accuracy positioning environment, in order to provide services that take advantage of the environment, we need to build a spatial information infrastructure, which includes maps. This article introduces our efforts to innovate map platform technology, which serves as the basis for developing various services in a high-accuracy positioning society, and the technical verification of seamless navigation, a new service that utilizes the map platform.

Keywords: seamless, 2.5D map platform technology, pedestrian navigation

1. Introduction

New products and services that integrate geospatial information and positioning technologies with information and communication technologies have been progressively emerging in recent years. Progress in this area is so rapid that some people are predicting that by 2020, automatically operated cars will be running on highways, and automatically operated construction machines will be working at construction sites.

Such products and services are expected to have a significant impact on our daily lives and to help build a more convenient, safe, and secure social environment. For example, even when people are in a strange place, they will not need to feel nervous because a click on their smartphone will enable it to guide the user through a complex underground mall or station in a manner that is appropriate considering the state of congestion in that location. The smartphone may even be able to automatically call a taxi. By sending information about the precise position to cars cruising automatically in the vicinity, users may be able to protect themselves against the risk of traffic accidents.

Such a society is called a high-accuracy positioning society. To achieve it, the Ministry of Land, Infrastructure, Transport and Tourism launched the High-Accuracy Positioning Society Project. This project promotes studies and feasibility tests on the spatial information platform for creating services that utilize indoor/outdoor positioning technology and map information, and on the required means and organizations for constructing the platform efficiently and effectively. It is expected that private companies will accelerate the creation of a diverse range of services by using this platform.

Various services are expected to be launched that will benefit society. The one we are focusing on is a seamless navigation service intended for guiding the user from his/her current location to the desired destination seamlessly and reliably, whether the route

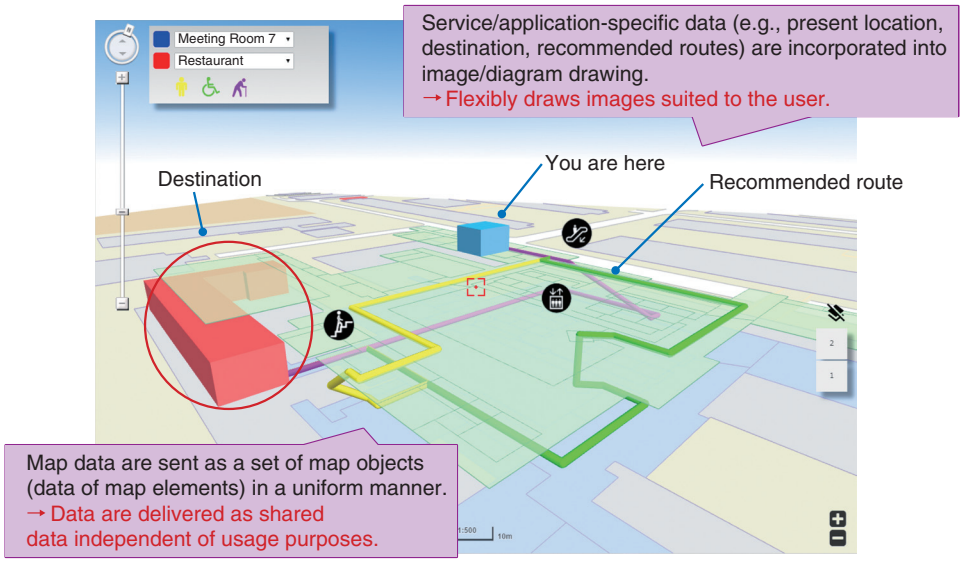


Fig. 1. Features of Parametric Map Platform Technology.

lies indoors or outdoors. We explain in this article our activities focused on developing map platform technology that will support the seamless navigation service.

2. Development of technologies for innovating seamless navigation

Two key technologies are necessary to achieve seamless navigation. One is map platform technology, which makes it possible to search for and display information (map information) about the surroundings. This includes graphic information such as topographic maps and the shapes of buildings, as well as information associated with them such as the names and attributes of buildings and facilities. The other is high-accuracy positioning technology, which pinpoints the user's current location with a high degree of accuracy.

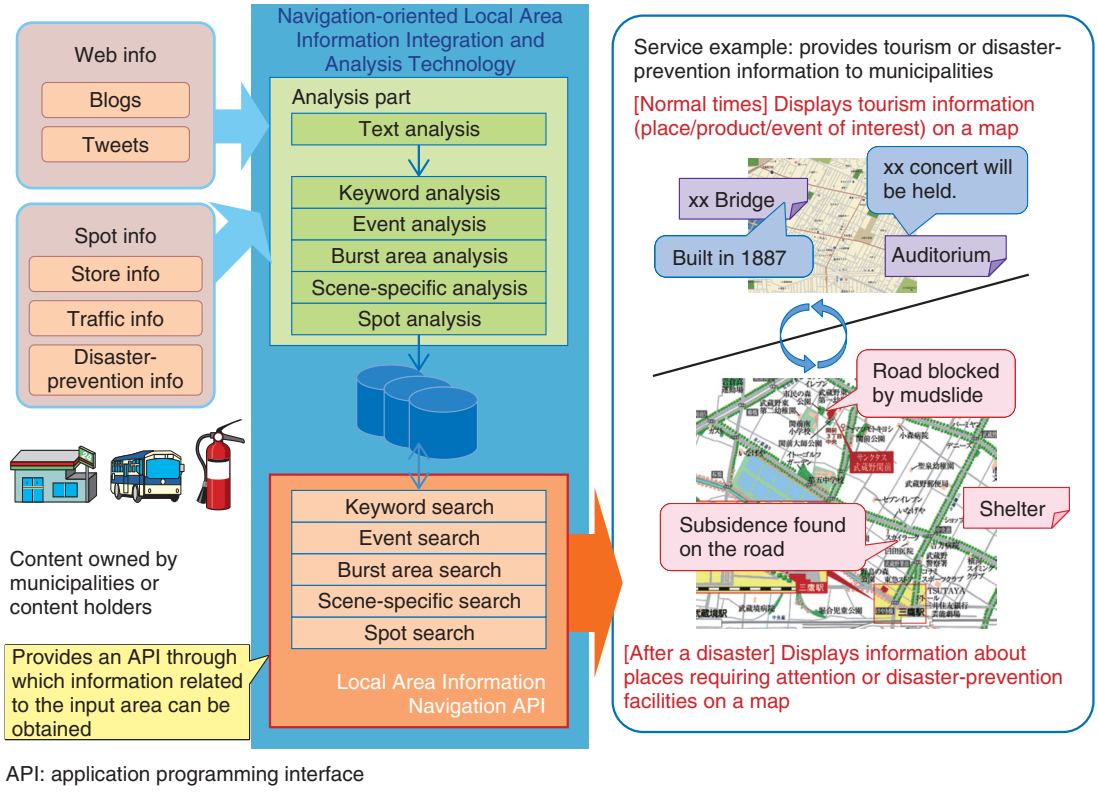
We are undertaking research and development (R&D) in the area of map platform technology, where we can draw on the elemental technologies that we have developed over time such as information search and text analysis and on our know-how regarding operation of a large-scale database. Three relevant R&D results are introduced below.

2.1 Parametric Map Platform Technology

Services that utilize electronic maps are already in widespread use. Many such services are regularly used on portal sites or through smartphone applications. As a rule, such conventional map services generate an image from map information that the service provider maintains and deliver it to the user's terminal where it is displayed. The upsides of this type of service are that data can be provided in a uniform manner for any service and that the processing load on terminals is low. The downsides are that it is difficult to vary the manner of map display for different services, and there are restrictions on adding service-specific information to a map.

To solve these problems, we have developed Parametric Map Platform Technology, which is a new platform technology for delivering and displaying maps. This makes it possible to create a different map for each different service and even for each user, or to create a new map by adding new information to an existing map. This technology delivers map data not in the form of a graph but in the form of data. It is the user terminal that creates a map from the delivered data. This makes it possible to flexibly create a map that is suitable for a particular service or for the particular situation of the user.

Map information delivered by the service provider can be kept intact, and new information can be added to suit the user's situation or need. For example, it will become possible to emphasize a landmark that is useful for navigation, such as a turning point on the route to a destination, by displaying it in 3D (three dimensions) (**Fig. 1**).



API: application programming interface

Fig. 2. Navigation-oriented Local Area Information Integration and Analysis Technology.

2.2 Navigation-oriented Local Area Information Integration and Analysis Technology

A large volume of text data transmitted daily via social media (blogs, social networking services, etc.) includes many items of information related to certain areas such as buildings/stores, stations, and streets. Few of these text messages indicate the exact location (e.g., address) of the object concerned. Therefore, it has been difficult to associate an object with a point on a map, except in cases where GPS (Global Positioning System) information is provided, as is the case in some media.

To solve this problem, we have developed Navigation-oriented Local Area Information Integration and Analysis Technology (**Fig. 2**), which analyzes location-related information (e.g., partial place names, station names, or store names) contained in transmitted text data in order to find the exact location and the subject matter of the text message.

For example, this technology can extract from social media sources fresh word-of-mouth information about an area, a building/store, a station, or a street on a map, and deliver it to the user using Parametric Map Platform Technology in order to suggest a route that might be interesting to the user at that time.

2.3 Seamless Navigation Information Management Platform Technology

To build a high-accuracy positioning environment and use it for services, it is necessary to develop a spatial information infrastructure. In particular, it is necessary to strengthen map information itself because it is essential that map information about all places (not only outdoor areas but also inside commercial buildings, underground malls, stations, etc.) within the range of our daily lives is available and ready for use.

However, the reality is that whereas there is an extensive volume of public and uniform digital information available on outdoor spaces that was created by the Geospatial Information Authority of Japan, indoor spatial information such as indoor floor maps has been created and used individually by different building owners. The data formats (**Table 1**) and the degree of precision of such data are so varied that it is

Table 1. Representative map data formats.

ID	Category	Format	Description
1	2D	Shape file (SHP)	Industry standard for handling map data in the vector format proposed by Esri
2	2D	SCADEC data eXchange Format (SXF)	Intermediate file format developed under the leadership of the Ministry of Land, Infrastructure, Transport and Tourism. It is used to exchange data between different computer-aided design (CAD) programs.
3	2D/3D	Drawing Exchange Format (DXF)	De facto standard used to exchange CAD drawings
4	3D	Filmbox (FBX)	Format designed to allow seamless exchange of 3D data between different applications
5	3D	Industry Foundation Classes (IFC)	Standard data exchange format for BIM (building information model)
6	3D	CityGML	XML-based file format defined by OGC (Open Geospatial Consortium). It is used to represent a 3D urban model.

GML: Geography Markup Language
SCADEC: standard for CAD data exchange in Japanese construction field
XML: Extensible Markup Language

virtually impossible to integrate them into cohesive indoor spatial data.

As a solution, we are developing Seamless Navigation Information Management Platform Technology. This will enable us to collaborate with building/facility owners that have such map data in order to maintain and expand the map data. The assumption is that graphic data such as topographic maps and buildings and attribute information such as building/store names and facility information will be provided by different owners at different intervals. The technology will offer capabilities for data conversion, data search/editing, and conditional data output (areas defined by longitudes and latitudes, building stories, attributes, etc.) in order to make it possible to input spatial data into a common coordinates base and to manage/edit and output data.

We also assume that map data created in this manner will be able to be processed using the Parametric Map Platform Technology in order to generate data that can be used for navigation. Since indoor floor plan data and attribute information will be added to the map data, the volume of data will be substantially larger than that included in a conventional map. We are studying ways to reduce the volume of communication and increase the processing speed by using a large volume of data for areas near the recommended route but a small volume of data for other areas.

3. Technical verification

It is important in R&D to create technology and improve it, but it is just as important to actually try it out and get feedback on its performance. In particular, navigation-related technology is not confined to terminals, applications, and users; it is only useful when it works in real places and environments.

We evaluated the technologies that we developed by taking part in a feasibility test conducted as part of the High-Accuracy Positioning Society Project. We selected this test because it allowed us to try out our technologies and the concept of seamless navigation (**Fig. 3**) and to use various high-accuracy positioning technologies that were already available on the market [1].

We used the Parametric Map Platform Technology to create a 2.5D map (flat plane + multiple floor levels) (**Fig. 4**) from the indoor map data provided. The 2.5D map represented both indoor and outdoor entrances and the floors of buildings both below and above ground level. We developed and tested an application that provided navigational information to the user based on passive triggers detected from the user's natural movements such as the manner of walking and the manner of holding a terminal, rather than from active clicks on menu buttons [2].

We confirmed that our technologies generally worked well in generating indoor/outdoor seamless maps and in providing navigation with a sufficient degree of tracking and response in the given indoor/outdoor positioning environment. In addition, we confirmed that the 2.5D map was an intuitive and easy-to-understand map representation. It was particularly useful for presenting a route to the back of a building or a route involving going up or down to different floors in a building. We also identified a number of issues that need to be addressed. They include interruption of navigation at locations where positioning data fluctuated widely—such as narrow streets between buildings and indoor/outdoor

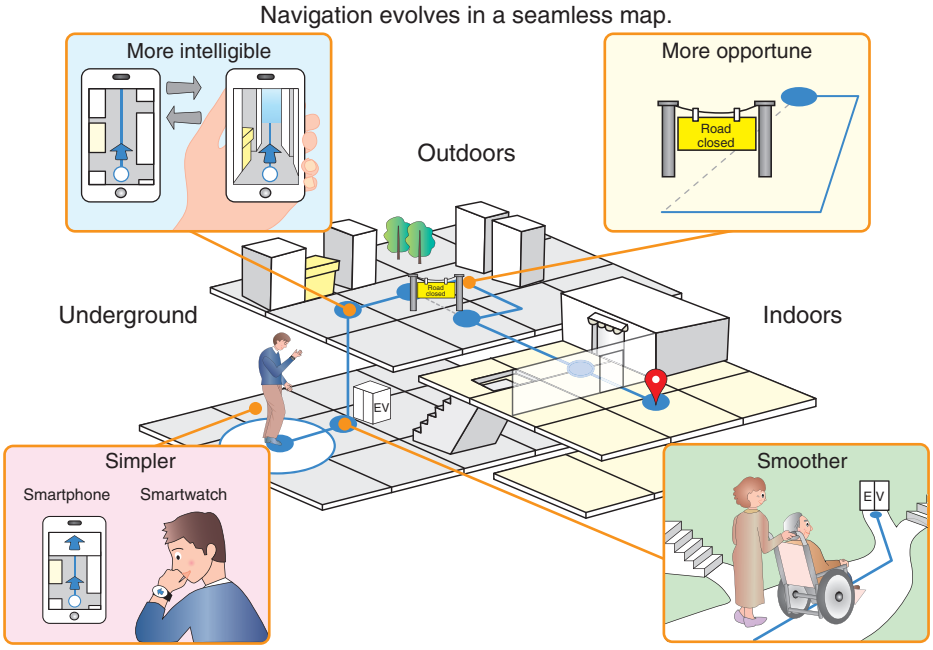


Fig. 3. Concept of innovation in seamless navigation.

Actual place

2.5D map representation

Map data source: High-Accuracy Positioning Society Project, Ministry of Land, Infrastructure, Transport and Tourism

Fig. 4. Example of 2.5D map representation.

entrances—and the difficulty in representing the heights of buildings and the layout of indoor facilities (e.g., determining which of several facilities is located in the front or in the back). We will study these issues as part of our ongoing technological development.

4. Future prospects

Services such as seamless navigation services intended for individuals in a high-accuracy positioning society cannot be realized solely through the technologies that we are developing. For example, we alone cannot develop high-accuracy positioning. These services cannot be realized without collaborative efforts by various players in both the public and private sectors such as by establishing a scheme and organization for maintaining and updating extensive map data. As a part of such collaboration, we plan to improve the technologies introduced here and create new technologies that will serve as a platform for producing new applications and services.

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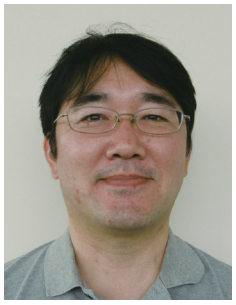
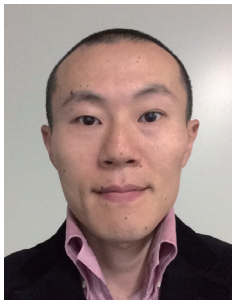
Hirofumi Abe
Senior Research Engineer, Proactive Navigation Project, NTT Service Evolution Laboratories.
He received a B.E. and M.E. in instrumentation engineering from Keio University, Kanagawa, in 1994 and 1996. He joined NTT in 1996. His current research interests include positioning and geographic information systems (GIS).



Shunsuke Konagai
Senior Research Engineer, Proactive Navigation Project, NTT Service Evolution Laboratories.
He received a B.E. in computer science from the University of Electro-Communications, Tokyo, in 1991. He joined NTT in 1991. His current research interests include GIS and the Internet of Things (IoT).

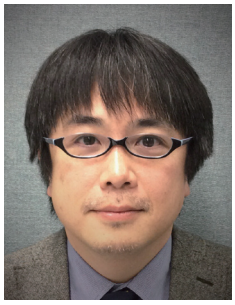
Shigeru Chiba
Senior Research Engineer, Proactive Navigation Project, NTT Service Evolution Laboratories.
He received a B.E. in management information science from Hokkaido Information University in 1996. He joined NTT in 1996. His current research interests include GIS and IoT.



Makoto Muto
Research Engineer, Proactive Navigation Project, NTT Service Evolution Laboratories.
He joined NTT in 2001 and engaged in research on information retrieval. He is currently developing a geospatial map engine featuring indoor, dynamic, and seamless navigation.

Mitsutoshi Nagahama
Researcher, Proactive Navigation Project, NTT Service Evolution Laboratories.
He received a B.E. and M.E. in information engineering from Yokohama National University, Kanagawa, in 2001 and 2003. He joined NTT in 2003. He is currently developing a geospatial map engine featuring indoor, dynamic, and seamless navigation.

Hitoshi Seshimo
Senior Research Engineer, Supervisor, Proactive Navigation Project, NTT Service Evolution Laboratories.
He received a B.E. and M.E. in mechanical Engineering from Waseda University, Tokyo, in 1995 and 1997. He joined NTT in 1997. His research interests include computer aided instruction, web-based learning, content distribution and navigation systems, and GIS.



Akihisa Kawanobe
Senior Research Engineer, Supervisor, Proactive Navigation Project, NTT Service Evolution Laboratories.

Yoshimasa Koike
Senior Research Engineer, Supervisor, Proactive Navigation Project, NTT Service Evolution Laboratories.
He received an M.E. in material chemistry from Tohoku University, Miyagi, in 1989. He joined NTT Information Processing Laboratory in 1989 and studied pattern recognition and computer aided instruction. During 1999–2005 he worked at NTT Resonant, where he developed a web-based learning system. He also worked at NTT Advanced Technology, where he built a support system for a virtual private server service. He is currently studying GIS.

Satoshi Fukada
Senior Manager, Transport and Mobility Business Producer, Strategic Business Creation Team, NTT Research and Development Planning Department.

Technology for Social Development of Accessibility Maps

Chihiro Yamamoto, Kaname Funakoshi, Hiroshi Konishi, Keihiro Ochiai, and Akihisa Kawanobe

Abstract

At NTT Service Evolution Laboratories, we are developing technology for creating information needed to support the mobility of elderly persons and the disabled. It consists of a crowd sensing function, which determines road gradients using a smartphone equipped with GPS (Global Positioning System) and an accelerometer, and technology for collecting information needed to support pedestrian mobility, which assists surveyors with no specialized knowledge. The objective is to achieve the capability to both collect and update information at low cost.

Keywords: accessibility map, pedestrian mobility support, pedestrian network

1. Introduction

With the accelerated aging of Japanese society, there is an urgent need to reinforce accessibility measures in order to support the elderly and persons with disabilities. Accessibility legislation (the Act for Promoting Easily Accessible Public Transportation and Facilities for the Aged and the Disabled) took effect on December 20, 2006. This has prompted efforts to make facilities—starting with train stations and public facilities—accessible according to guidelines formulated by individual municipalities.

Along with these efforts, municipalities, social welfare councils, and volunteer organizations are collaborating to create accessibility maps that provide information about surface conditions, road widths, and the presence of barriers such as curbs along streets, bumps on roads, and steps on sidewalks in key districts designated by municipalities, and to provide information about the availability of multi-purpose restrooms, ramps, and elevators in public facilities.

To ascertain actual needs, we interviewed persons with disabilities and the organizations that support them, and we identified three major requirements. First, persons with mobility issues want reliable information about places that they would visit only occasionally, rather than those that they frequent in the course of everyday living. Second, they want information about not only public facilities but also facilities that help them to enjoy life. Third, persons with mobility issues use various ways of getting around such as walking unaided, walking with the aid of canes or walkers, and riding in regular and electric wheelchairs, and they want to know about routes that are suitable for each of those means. This article focuses on the third requirement and discusses how to collect and update data that are relevant for different means of mobility.

2. Regional efforts to gather and utilize data

Many communities have implemented initiatives in which a large number of citizens cooperate to collect accessibility information for a wide area, rather than just for selected areas. One internationally recognized activity is Wheelmap [1] run by Sozialhelden e.V., a nonprofit organization (NPO) in Germany. In Wheelmap, surveyors, called *mappers*, enter information about the wheelchair compatibility of each facility on OpenStreetMap [2].

There are many other initiatives being undertaken by states or municipalities. Omuta City in Fukuoka Prefecture has gathered and compiled information about the accessibility statuses of some 20 km of

Table 1. Data necessary to support pedestrian mobility.

Barrier-related data		Examples
Facility-related data	Information about facilities at or on the way to the destination	Examples of buildings: government offices, hospitals, and convenience stores
		Examples of other facilities: multi-purpose restrooms, ramps, and elevators
Route-related data	Information about the presence of obstacles	Gradients, steps, widths, and presence of handrails

roads and 22 facilities along tourist routes, including the city's downtown area and facilities related to the historic Miike Coal Mine, which has been listed as a United Nations World Cultural Heritage site, in order to be ready to welcome tourists [3].

Matsue City in Shimane Prefecture has integrated public facility data managed by the Shimane Prefecture government, accessibility data owned by a local NPO, and facility data managed by the Matsue City government in order to provide data required by a pedestrian mobility support service. The city is working with Shimane University and local information technology enterprises in order to provide and utilize this information as open data [3].

Kamakura City in Kanagawa Prefecture has added information collected by a local NPO and volunteers on the availability of multi-purpose restrooms and ramps to the basic information about its shared facilities. Five municipalities on the Miura Peninsula (Yokosuka, Hayama, Kamakura, Zushi, and Miura) are promoting the provision of accessibility information as open data. Three cities in the region (Kamakura, Yokosuka, and Yokohama) are holding joint hackathons [3].

3. Identifying issues and setting goals

As of April 1, 2013, Japan had more than 1.2 million km of roads, including those managed by the state and those controlled by municipalities [4]. Clearly it would cost an enormous amount of money to collect and update information about all of these roads every year, and several issues would need to be addressed. First, it is important to reduce the cost of data collection and updating. One solution would be to invite citizens to participate in surveys. While this would make it possible to survey wide areas, it would be difficult to ensure that the collected information conforms to standard criteria because members of the public do not have specialized knowledge. Consequently, one issue is how to collect standardized information.

Next, it is necessary to identify what types of information must be collected. To provide reliable accessibility information about a route, it is necessary to have information about facilities at or en route to the destination and information about the streets and pathways regarding the existence of hills or steps (**Table 1**). Then it is necessary to develop accessibility information about routes and destinations by overlaying the collected information on the logical road data, which is known as network data. Finally, additional information is needed in order to present the network data to users. For example, if network data are to be presented on a map, map data are required. If the direction in which the user should progress is to be indicated, information about the user's current position is required.

In 2010, the Ministry of Land, Infrastructure, Transport and Tourism released Draft Specifications for Pedestrian Network Data [5]. It defined a data structure for developing information about a network that consists of nodes and links to indicate whether or not they are usable by pedestrians, and for overlaying a variety of information about pathways and facilities on the network (**Fig. 1**). However, pedestrian network data involve such detailed definitions that they can only be developed by specialists in survey technology. Such surveying also tends to be costly, at 100,000 yen/km [6].

To reduce this cost, we are seeking to present standards for data entry to surveyors in an easy-to-understand manner, avoiding extreme precision but still conforming to the pedestrian network data specifications. This would enable even non-specialist surveyors to collect information for use in pedestrian network data. An important issue here is how to ensure that the collected data are sufficiently precise for practical purposes.

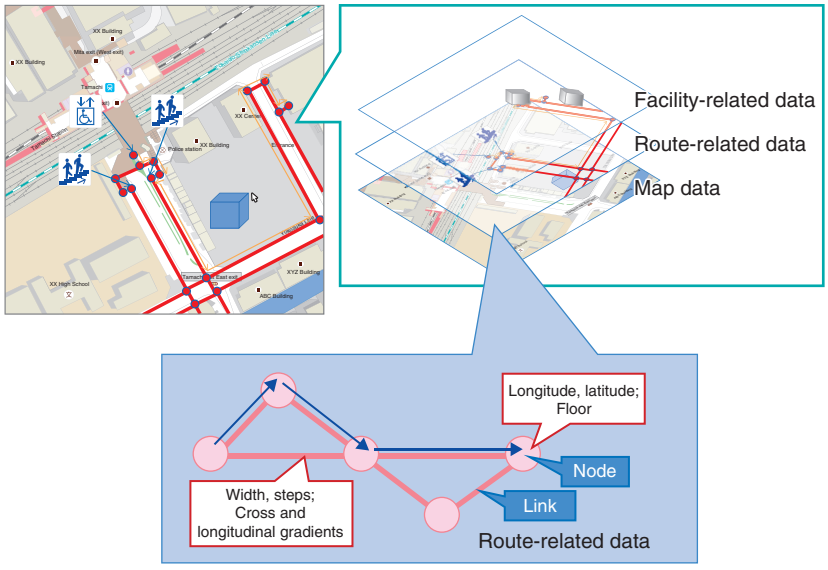


Fig. 1. Overview of Draft Specifications for Pedestrian Network Data 2010.

4. Technology for generating information needed to support pedestrian mobility: MaPiece

We are developing MaPiece, a technology for generating information needed to support pedestrian mobility, with a view to reducing costs for information generation and updating, while retaining sufficient data precision for supporting pedestrian mobility. This technology consists of two technical elements.

4.1 Crowd sensing technology

The first element is crowd sensing technology. This determines if a particular road is flat enough for wheelchairs using data from sensors such as accelerometers, Global Positioning System (GPS), and barometers, which are built into a smartphone. This technology detects barriers to wheelchairs (steps or slopes with gradients greater than five degrees) and selects routes that are flat enough for wheelchair use. Most smartphones have GPS and accelerometers. A smartphone application that implements this technology collects GPS and sensor information for each step to be taken by the surveying pedestrian. Machine learning is used to determine from the collected data whether the road surface is flat or has steps or slopes with steep gradients. This information is combined with GPS information and overlaid on a map.

A survey by a single pedestrian may not be sufficiently accurate or could involve GPS information errors. Therefore, we combine the survey results of many pedestrians to reduce the effects of errors and determine which roads are flat enough for wheelchair use (**Fig. 2**). However, other types of information cannot be surveyed using sensors in smartphones, for example, road width and availability of multi-purpose restrooms, elevators, and parking spaces for vehicles carrying persons with disabilities.

The extent of GPS error depends on the GPS measurement environment, for example, whether it is indoors or outdoors. In particular, the extent of error is greatly affected by the presence of a shielding object if GPS/GNSS* is used. Thus, this technology works best when used in an outdoor area that is free of shielding objects.

4.2 Technology for collecting information needed to support pedestrian mobility

The second technical element is aimed at enabling persons with no specialized knowledge to use tablets to collect information needed to support pedestrian mobility. Paper is most often used in surveys for collecting information needed to generate accessibility maps. In contrast, this technology makes the most of tablets. Existing information and information about

* GNSS: General term for a global navigation satellite system. The United States operates GPS, and Russia is rebuilding GLONASS. The European Union is currently developing Galileo, and Japan is developing the Quasi-Zenith Satellite System.

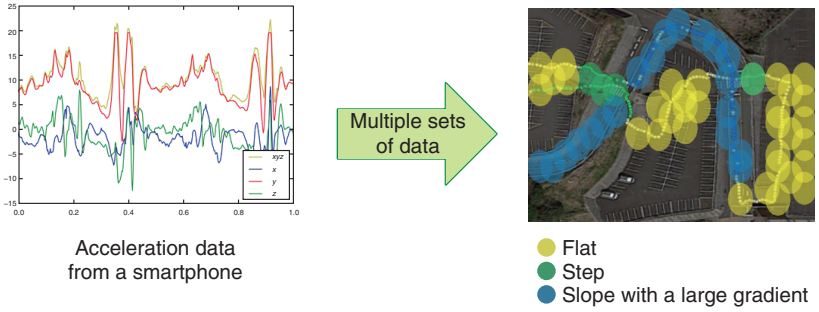


Fig. 2. Crowd sensing technology.

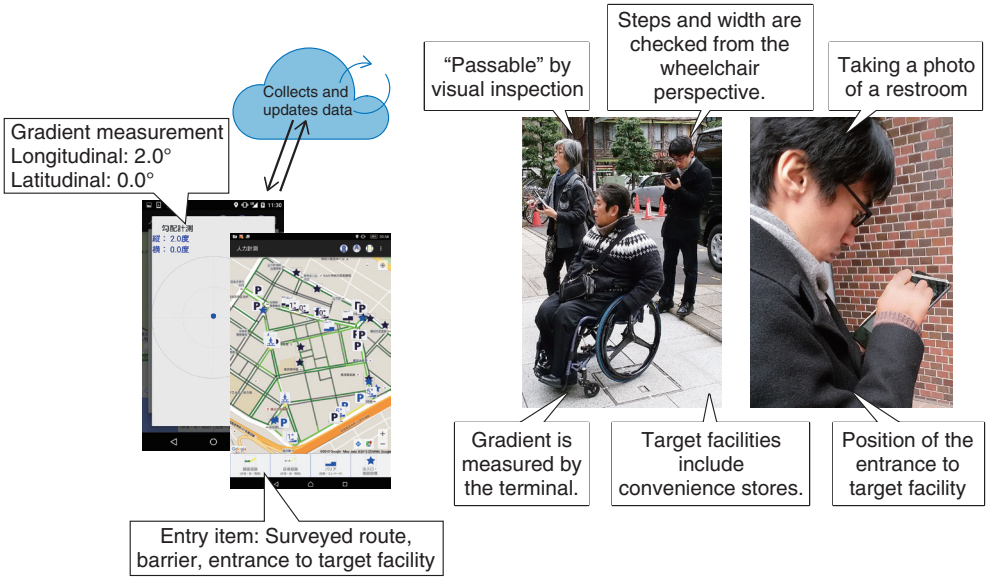


Fig. 3. Technology for collecting information needed to support pedestrian mobility.

the objects to be surveyed are stored in advance and displayed on the tablet during surveying so that the surveyor does not need to enter such information. Upon completion of a survey, information collected by individuals is gathered via a communication network.

When a surveyor detects a barrier or a certain type of facility, he/she can select the appropriate entry item on the map and enter, for example, the gradient of a slope measured by a built-in sensor, or take a photo of the particular site (**Fig. 3**).

5. Experiment and evaluation

To evaluate this technology, we carried out an experiment in the Yamate district and four other areas in Naka-ku, Yokohama City, Kanagawa Prefecture, in November-December 2015.

5.1 Experiment on crowd sensing technology

We evaluated how accurately this technology could determine road surface conditions (flat or the presence of steps or slopes with steep gradients) and select flat roads in a field trial. A total of 72 surveyors participated in the experiment. They carried smartphones with built-in sensors and walked along designated roads with different surfaces. The smartphones were carried in different places (pockets or bags) and at different angles. Some examples of the experimental results are shown in **Fig. 4**.

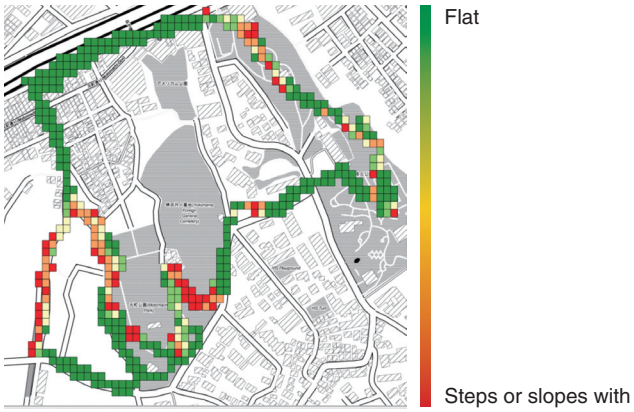


Fig. 4. Determination of flatness using crowd sensing technology (Yamate district).

The measured data were compared with correct data. It was found that flat roads were identified with an accuracy of 70% or higher.

5.2 Experiment on technology for collecting information needed to support pedestrian mobility

We developed an application that runs on tablets. To evaluate the efficiency and accuracy of data collection, we asked surveyors without specialized knowledge in land measurement or on the information to be collected to participate in this experiment.

This experiment involved two different surveys:

1) Survey 1: This survey was conducted by a team comprising one person in a wheelchair and two able-bodied persons, all of whom were well versed in the application and the information to be collected.
2) Survey 2: This survey was conducted by a team comprising one person in a wheelchair and two able-bodied persons, none of whom had specialized knowledge on the application or the information to be collected.

Members of each team shared, as appropriate, the tasks of determining problematic areas on sidewalks, measuring widths and gradients, and entering data in a tablet. In each of the five districts, Survey 1 was conducted once, and Survey 2 was conducted six times.

Survey 1 recorded an accuracy of 97% or higher, and the survey cost was less than one-tenth the cost of conducting measurements with specialist surveyors. The accuracy of Survey 2 was somewhat lower than that of Survey 1. This result enabled us to identify issues regarding instructions to be given to surveyors and issues to be addressed to improve the application.

6. Future prospects

The above experiments have given us confidence that information about pedestrian routes can be collected at low cost without sacrificing accuracy. We are now improving the crowd sensing technology to raise the accuracy of identifying flat roads and also to enhance the functionality and operability of the technology for collecting the information needed to support pedestrian mobility.

Our future plans include extending the current technology to cover indoor areas by combining it with the seamless navigation information management platform technology, conducting a study on a full-fledged pedestrian mobility support smartphone application, combining the collected information with information about roads on which wheelchairs have actually traveled successfully, and developing technology that supports pedestrians with visual impairments.

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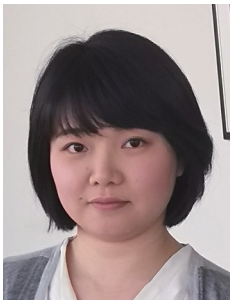
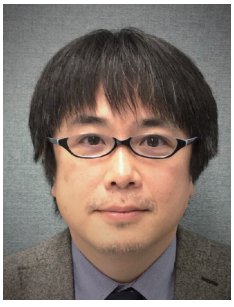


Chihiro Yamamoto
Researcher, Proactive Navigation Project, NTT Service Evolution Laboratories.
She received an M.E. in global information and telecommunication studies from Waseda University, Tokyo, in 2008 and joined NTT the same year. She is currently studying technology for social mapping of accessibility information.

Kaname Funakoshi
Research Engineer, Proactive Navigation Project, NTT Service Evolution Laboratories.
He received a Master's degree from Japan Advanced Institute of Science and Technology, Ishikawa, and joined NTT in 1997. His research interests include information retrieval and social network organization. He is a member of the Information Processing Society of Japan, the Institute of Electronics, Information and Communication Engineers (IEICE), and the Association for Computing Machinery.

Hiroshi Konishi
Senior Research Engineer, Proactive Navigation Project, NTT Service Evolution Laboratories.
He received a B.E. and M.E. in computer science and information mathematics from the University of Electro-Communications, Tokyo, in 1991 and 1993. He joined NTT in 1993. He has been engaged in research and development of pedestrian mobility support systems. He is a member of IEICE and the Acoustical Society of Japan.

Keihiro Ochiai
Senior Research Engineer, Proactive Navigation Project, NTT Service Evolution Laboratories.
He received a Ph.D. in information & computer sciences from Toyohashi University of Technology, Aichi, and joined NTT in 1994. His research interests include indoor positioning and navigation. He is a member of IEICE.



Akihisa Kawanobe
Senior Research Engineer, Supervisor, Proactive Navigation Project, NTT Service Evolution Laboratories.

Development of a Mobile Personal Agent that Expands Human Potential

Tatsuya Ishihara, Masanao Nakano, Takayoshi Mochizuki, Tomohiro Yamada, Shin Mitsuhashi, and Muneaki Fukuoka

Abstract

NTT is developing a personal agent that understands us, interacts with us, and supports us in growing by being with us in the real world. This article focuses on personal mobility as one application area for this agent. The prototype mobile personal agent provides interactive training on how to operate a personal mobility vehicle for first-time drivers of such vehicles, prompting them to discover what operations are required and enabling them to improve their operating skills.

Keywords: personal agent, personal mobility, driving support

1. Introduction

In recent years, there has been growing interest in personal mobility vehicles, which are vehicles for short-distance travel for small numbers of people. These include two-wheeled self-balancing electric vehicles, micro-electric vehicles, and electric wheelchairs. It is forecast that the value of the market for these vehicles will expand to 120 billion yen by 2020 [1]. Against this background, NTT DOCOMO proposed the provision of an *Environment for Comfortable Transportation* as part of the initiative *Business Creation in View of 2020* in its *New Initiatives Toward Delivery of Medium-term Targets* announced in April 2015 [2]. Specifically, NTT DOCOMO established DOCOMO BIKESHARE with joint investments by NTT Urban Development, NTT DATA, and NTT FACILITIES [3]. As the name indicates, DOCOMO BIKESHARE is a bicycle sharing business. In addition, NTT DOCOMO concluded a business alliance with WHILL KK. [4] to undertake a mobility sharing business using a personal mobility vehicle called the WHILL Model A [5]. The NTT Group is expected to further accelerate entry into this market.

2. Use of ICT in a personal mobility sharing service

We believe that two types of ICT (information and communication technology) have applications in a personal mobility sharing service. One is automation of the operational guidance provided for users. Since personal mobility vehicles are unfamiliar to first-time users, it is necessary to teach users how to perform such functions as powering-on the vehicle. If such operational guidance can be provided without human intervention, the workload on staff who handle the renting out of personal mobility vehicles can be reduced. The second application is automated assessment of the skill levels of personal mobility users. The number of traffic accidents involving electric wheelchairs, which have already been widely adopted, is increasing. Since no driving or user license is required to operate an electric wheelchair, there are many users who have not had sufficient practice. To prevent accidents, it is necessary to assess the operational skill level of users. However, it is difficult to determine whether or not a particular user is sufficiently skilled. Provision of the results of automatic assessment as feedback will encourage users to pay more attention to operations and help them to

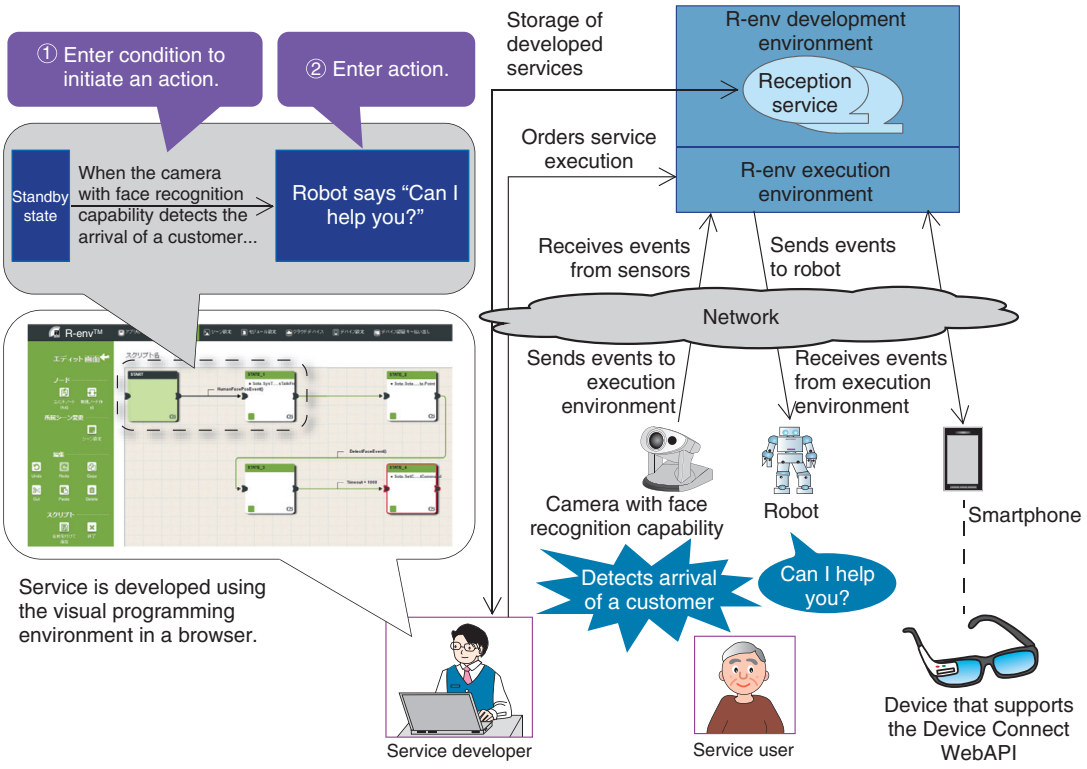


Fig. 1. Development of a device-associated service using R-env™.

improve their skills.

3. NTT activities

NTT is developing a cloud-based interaction control technology called R-env™ [6] (**Fig. 1**) that makes it easy to develop applications that focus on interactions with humans. The objective of this technology is to achieve a cloud-based multi-device interaction service that expands the potential of people by understanding their statuses and conditions through verbal and non-verbal communication between them and various robots, sensors, and other devices that surround them, and by using this understanding to encourage new actions and to enhance their awareness of their surroundings.

R-env provides a cloud environment that allows device-associated services (i.e., services that combine robots, sensors, gadgets, and applications) to be developed, debugged, and executed using a single browser. Anyone can easily develop device-associated services by creating a state transition diagram that combines the actions of devices connected to R-env and conditions for transitions to the next actions using the graphical user interface of a browser. We have developed a prototype personal agent that can be used when a personal mobility vehicle is connected to a device such as a smartphone. The agent understands the user’s operational status and operational skill level from information gleaned from the user’s interactions with the personal mobility vehicle such as his/her dialog with and operations of the vehicle, and uses this understanding to provide feedback such as prompting operations through a dialog or otherwise enhancing his/her awareness about operations. The personal agent applied to personal mobility will provide operational guidance and rate the driver’s level of operational skill without any need for human intervention.

4. Joint experiment by three companies

To evaluate the effectiveness of this mobility-assisting personal agent, NTT Service Evolution Laboratories, NTT DOCOMO, and WHILL initiated a joint experiment on October 27, 2015 [7]. Specifically, NTT DOCOMO’s mobility sharing system [8] was installed in each WHILL Model A personal mobility

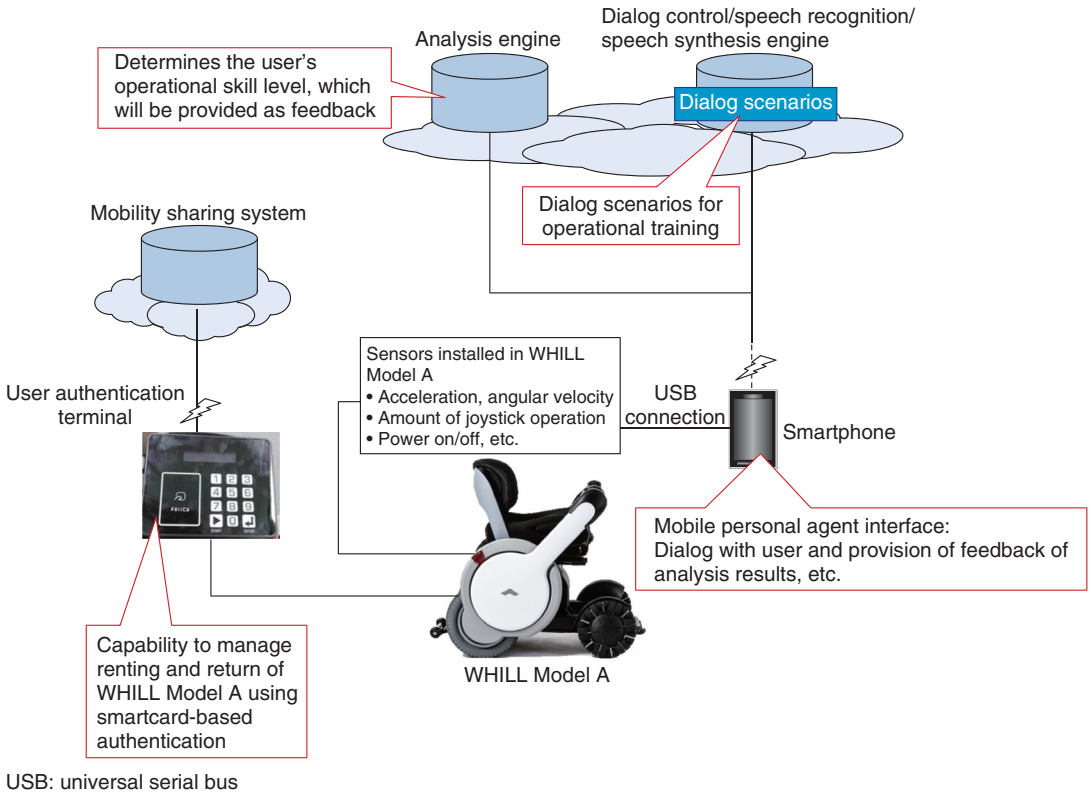


Fig. 2. Overview of associated device and analysis engine.

vehicle, and the prototype personal agent was installed in the WHILL Model A and in a smartphone (**Fig. 2**). In the agent, the analysis engine for determining the driver's level of operational skill, and the dialog control and speech synthesis technologies, all developed by NTT, work together. This experiment is aimed at assessing the effectiveness of operational training given to a first-time driver through a dialog with the agent.

The operational training developed by NTT has three features. First, the linkage between a WHILL Model A and a smartphone turns the WHILL Model A into a robot. As a mobility vehicle, the WHILL Model A is characterized by its excellent design, operability, and running ability. Incorporation of a smartphone into a WHILL Model A makes it possible to implement various personal agent functions such as dialogs with the user, displaying of images, determination of the user's operational status from the analysis of data from sensors installed in the WHILL Model A, and provision of feedback of analysis results to the user.

Second, it is possible to provide operational training that is linked to data from sensors in the WHILL Model A. It is important that the operational guidance items provided to the user are given based on a particular user's operational status. The mobility-assisting personal agent ascertains the user's operational status through data obtained from various sensors and provides operational training appropriate for the situation. This enhances the effectiveness of the training.

Third, the level of operational skill of the user can be determined. At present, there is no benchmark for operational skills of personal mobility users, as is the case with the operation of electric wheelchairs, even though the latter are becoming increasingly popular. The Rehabilitation Center for Persons with Disability and the Association for Technical Aids provide a practice checklist [9]. However, the checklist only identifies items of required practice such as how to power-on an electric wheelchair and other basic operations, and how to move forward or turn right or left. It does not provide any way of determining if the user is able to satisfy each item in the checklist.

Noting that smartphones have acceleration and angular velocity sensors, we developed our own

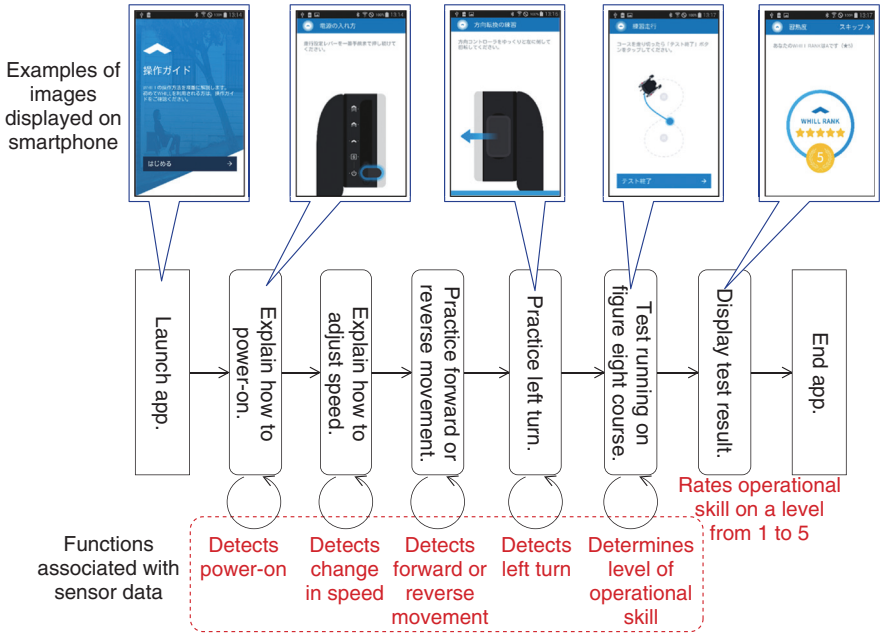


Fig. 3. Overview of operational training.

operational skill benchmark [10] based on the data from such sensors mounted on the WHILL Model A, and implemented it as part of the mobility-assisting personal agent function. The operational training includes training in such basic operations as powering a vehicle on/off and adjusting the speed, basic running operations such as moving forward and turning right or left, and finally, steering a figure eight course, which is used to provide feedback on his/her operational skill level to the user (**Fig. 3**).

5. Feasibility test on Soleil Hill

To evaluate the effectiveness of the mobility-assisting personal agent with the above features in providing operational training, we conducted a feasibility test of a WHILL Model A sharing service with visitors to Nagai Uminote Soleil Hill [11], Yokosuka City, from November 10 through December 9, 2015. Soleil Hill is a large, barrier-free park with a variety of amenities, including a restaurant, spa, and playground equipment, and is thronged with visitors on weekends. This site was selected because it was expected that there would be many visitors who could be targets for the sharing service, namely, those who can reach the park entrance by car but cannot walk around in the park, or those who like to try out new vehicles. Two WHILL Model A units were stationed at the entrance to Soleil Hill. Anyone wanting to apply to ride one of the vehicles was requested to learn how to operate the vehicle without assistance before venturing out into the park. The feasibility test examined whether or not the number of staff members needed to explain operation of the WHILL Model A could be reduced and if it was possible to accurately determine an individual applicant's operational skill level. People ranging in age from their 20s to their 90s rode the WHILL Model A units. It was confirmed that the operational training given by the personal agent was able to eliminate user concerns about operating a WHILL Model A. There was no significant gap between the level of operational skill determined by the personal agent and the user's self-assessment thereof [12]. Thus, we were able to confirm that the operational training given by the agent was effective.

6. Future prospects

The joint experiment confirmed that the operational training given by the mobility-assisting personal agent was effective. We are preparing to study an operational skill-rating method that does not simply assume a flat road but takes other road conditions such as brick paving and slopes into consideration, because the current benchmark for the level of

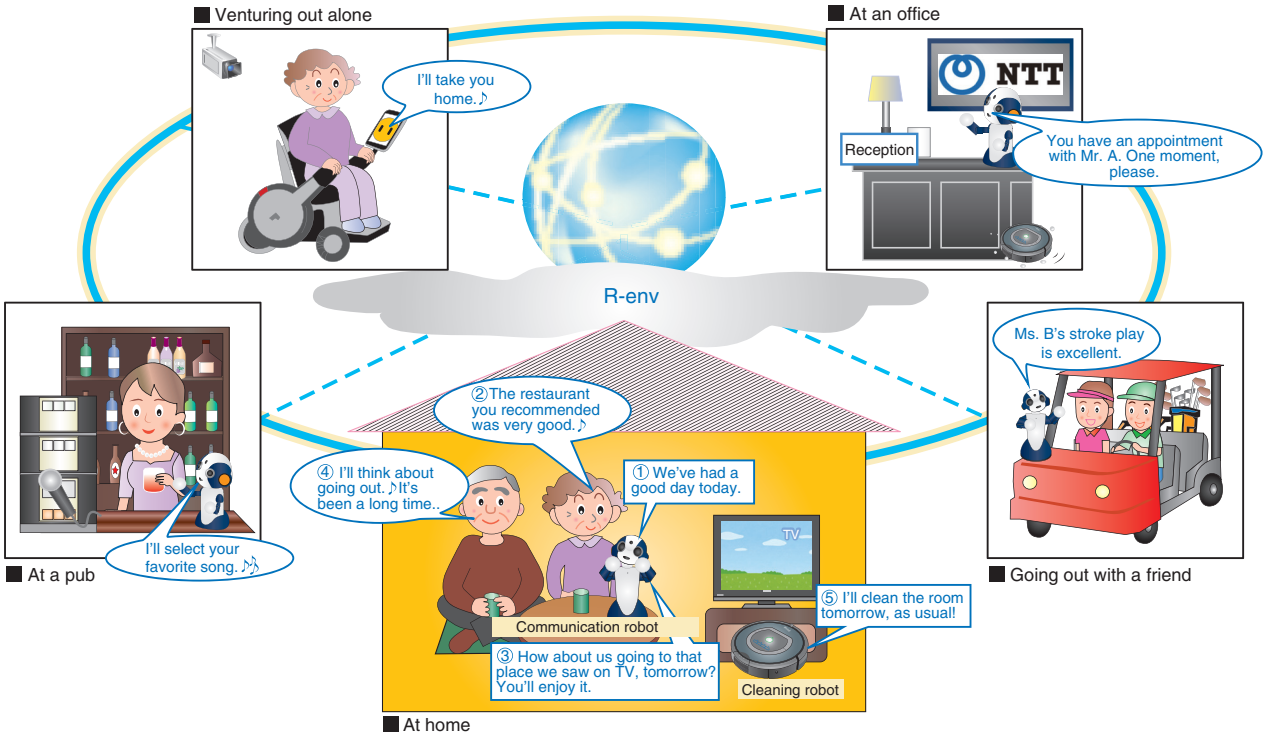


Fig. 4. Concepts of services made possible by R-env.

operational skill does not take road conditions into consideration. We also aim to enable various indoor and outdoor devices to work together in order to provide a variety of empowering services that adapt to each user's conditions. These include a navigation service that enables personal mobility users to avoid barriers and a running assistance service that assists personal mobility users based on the user's condition and the environmental conditions. Furthermore, we plan to increase the number of partner enterprises that use R-env and the number of devices that can be connected to it so that personal agents can operate on various devices, including communication robots and home appliances. Our goal is to accelerate the realization of a world in which such personal agents make use of information about not only users' mobility but also their current situations, in order to understand their conditions, interact with them, and enable them to recognize what actions are required (**Fig. 4**).

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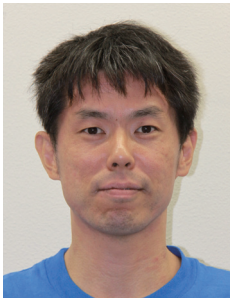
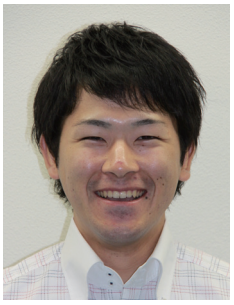
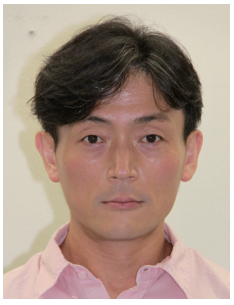


Tatsuya Ishihara
Research Engineer, Networked Robot & Gadget Project, NTT Service Evolution Laboratories.
He received an M.E. in information science and technology from the University of Tokyo in 2006. He joined NTT Cyber Solutions Laboratories in 2006. From 2011 to 2014, he was with NTT EAST. He joined NTT Service Evolution Laboratories in 2014. His research interests include robotics and human-machine interfaces. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE) and the Robotics Society of Japan (RSJ).



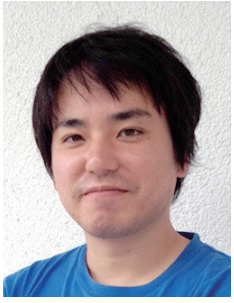
Masanao Nakano
Researcher, Networked Robot & Gadget Project, NTT Service Evolution Laboratories.
He received an M.E. in information science from Kobe University, Hyogo, in 2014. He joined NTT Service Evolution Laboratories in 2014. His research interests include data analysis and human-robot interaction.



Takayoshi Mochizuki
Senior Research Engineer, Networked Robot & Gadget Project, NTT Service Evolution Laboratories.
He received an M.A. in human sciences from Waseda University, Tokyo, in 2001. He joined NTT Service Evolution Laboratories in 2014. His research interests include human-robot interaction and human-machine interfaces.

Tomohiro Yamada
Executive Research Engineer, Supervisor, Networked Robot and Gadget Project, NTT Service Evolution Laboratories.
He received an M.S. in electronics engineering from Niigata University in 1992 and an MBA from the University of Birmingham, UK, in 2007. He joined NTT in 1992 and has been conducting research on content distribution systems and technologies to support human-robot communication. He is the W3C (World Wide Web Consortium) Advisory Committee Representative of NTT and also a member of the Association for Computing Machinery, the Institute of Electrical and Electronics Engineers, and the Information Processing Society of Japan.

Shin Mitsuhashi
Assistant Manager, Smart-life Solutions Department, NTT DOCOMO, INC.
He joined NTT Communications in 2004 and moved to NTT DOCOMO in 2012. He is currently involved in mobility share business endeavors.



Muneaki Fukuoka
Chief Technology Officer, WHILL KK.
He worked for Olympus Corporation as a medical device engineer from 2008 to 2012 and joined WHILL as one of three founders in 2012.

Agile Development of JR East App Designed to Enhance Customer Service Quality

Takashi Ogawa and Takayuki Matsumoto

Abstract

East Japan Railway Company (JR East) is a leader in the country's railway industry and provides passenger railway services in the Kanto, Koshinetsu, and Tohoku regions. It is also engaged in a wide variety of related business activities. In March 2014, as part of the initiative to utilize information and communication technology included in its New Management Vision formulated in 2012, JR East released JR East App, its official smartphone application. This article gives an overview of that application and describes the agile development adopted by NTT Software in creating it.

Keywords: smartphone application, agile development, transportation operation status

1. Introduction

East Japan Railway Company (JR East) simultaneously released Android[*1] and iOS[*2] versions of JR East App in March 2014. This was its first official application, although the company had earlier released a few experimental or short-term applications. The official app was downloaded 400,000 times in the first month after its release, 1 million times in the first year, and 1.6 million times by February 2016.

The application received the Good Design Award in 2014 and the Minister of Internal Affairs and Communications Award in the MCPC (Mobile Computing Promotion Consortium) Awards in 2015. It is still evolving.

The current version of the JR East App provides information about the operational status of all lines run by the company, timetables, the current locations of trains, temperatures inside train cars, and the congestion status of trains on selected lines. In addition, it offers information on the floor plans of stations, coin-operated lockers, and other station facilities. It also offers convenient features such as displaying train delay certificates. We have put in place a database and an application programming interface (API) through which the database can be accessed to retrieve information so that the application will be able to serve as a platform for utilizing information from both within and outside of JR East.

2. ICT Information Transmission Project launched as part of New Management Vision

In 1987, the then Japan National Railways was privatized and geographically divided into six regional railway companies, of which JR East is one. It operates a railway network extending 7400 km and comprising 69 lines across a large area that encompasses the Kanto, Koshinetsu, and Tohoku regions. Every day, some 17 million people use JR East trains. In addition to its core business of passenger railway services, JR East is involved in a wide range of related business activities such as operating kiosks and on-train sales. It also owns and operates shopping and office complexes. Today, these facilities constitute an important social infrastructure that is a vital part of Japan's economic activity.

*1 Android is a registered trademark of Google Inc.
*2 iOS is a trademark or registered trademark of Cisco in the U.S. and other countries and is used under license.

In 2012, the company formulated the *JR East Group Management Vision V—Ever Onward*, the fifth management vision since the foundation of the company. The vision defines the company's future management direction, taking into consideration major environmental changes such as the Great East Japan Earthquake. It consists of two priority initiatives: its *eternal mission*, which involves pursuing extreme safety levels, reforming service quality, and strengthening collaboration with local communities, and its *pursuit of limitless potential* such as achieving technological innovation, tackling new business areas, developing employees, and creating a corporate culture that maximizes human potential.

As part of this vision, JR East decided to study anew the utilization of information and communication technology (ICT) to enhance customer service quality. Specifically, a project was initiated for the purpose of studying how to provide information to customers more effectively. In the course of this project, it was decided to further improve the experimental service called Train Net, which had been introduced a few years earlier by the Research & Development Center of the JR East Group, and to convert it into an official, commercialized application. The ICT Information Transmission Project was launched in order to develop the application.

3. Agile development adopted by NTT Software

In the initial stage of development of JR East App, there was a great deal of enthusiasm among those taking part in developing JR East's first full-fledged application. A lot of individuals from all relevant departments within JR East, relevant subsidiary companies, and vendors participated in project meetings. Believing that the application would serve as the face of the company, they gave priority to studying the design of the application, that is, the user interface. This meant that technical studies on the system configuration, functionality, and performance were placed on the back burner. To remedy this situation, NTT Software was invited to participate in the project for the purpose of addressing the system development aspect.

The aim is to provide information that is well suited to the particular context of the customer by gathering the necessary content from both within and outside of the JR East Group. In particular, JR East focused on creating a sense of *information sharing* and a sense of an *image gap*. Creating a sense of information sharing among customers refers to providing information about stations and about the operational status of trains. Creating a sense of an image gap refers to being able to provide content that does not, on the face of it, seem to fit with the conventional, staid image of a railway company. For example, we would make an innovative attempt to provide information about the congestion status of trains, or provide entertaining content such as cartoons that could be enjoyed during brief idle times on a train.

Another objective for this application was to establish an information platform that would be useful not only from a service perspective but also from business and operational perspectives. Therefore, vendors that had developed individual existing systems that provide information about train operational status, or information about internal conditions of cars, were invited to participate in developing the application. Unlike the conventional railway software systems that they had been building for many years, smartphone applications and the information that they process are updated frequently. Therefore, it was necessary to break away from the conventional system development approach, starting with defining the requirements.

To enable early release of the application, NTT Software adopted an agile development method in which project members were divided into two teams. The day after decisions were made and the general directions of proposed solutions were determined in meetings, the solutions were implemented. Templates were created for the content management system using Grails [1]. Automatic builds in Jenkins [2] were adopted in order to boost development speed and efficiency.

Formerly, JR East had tended to custom-build its systems. In contrast, the development of JR East App incorporated existing proven platforms and convenient tools. As a result, the application was developed in only six months, which is half the time required for conventional development projects. The development cost was also cut dramatically.

We believe that the cordial relationships among the development project members, based on trust that was nurtured through intensive exchanges of opinions and discussions in weekly meetings, have been major factors in making this project a success. Because the development organization was well thought out, discussions in meetings were not carried over to the next meeting, and specific policies were determined in each meeting.

We used three project management tools (Redmine [3], Subversion [4], and Git [5]) which had been

introduced to NTT Software. They enabled visualization of the project status and progress and were useful for managing the work by multiple vendors.

4. Proposals implemented to facilitate project management

The Yamanote Line Train Net capability provided by the application visually presents information about the congestion status and internal temperature of each car in each train. Sensors installed in each car send data every 20–30 seconds, so the total volume of data that needs to be stored and processed is huge. Studying how to store, manage, and use such data to develop new services or enhance service quality was a major issue. This would not have been possible without having put a firm development platform in place.

There were some customer-related issues in addition to the system-related issues mentioned above. To address these issues, NTT Software proposed building a data warehouse infrastructure and using a business intelligence tool called Yellowfin [6]. These were adopted and have been helpful in managing the project.

5. Expectations for use toward 2020

Two years have passed since JR East first released this application. During that period, the program has been updated monthly to reflect the demands of customers and users. The capabilities of the application have been steadily expanded. My Line Setting, which enables users to quickly check the operational status of trains, has been extended to cover the 51 lines of the 15 private railways in the Tokyo metropolitan area. Train Location Information was also extended to cover a total of 17 lines (by March 2016). We are also working to provide more customer-friendly services that collaborate with other applications, for example, providing information about other transport systems available at each station (e.g., buses and taxis), and linking information with digital signage units inside train stations. The English-version application called JR-EAST Train Info (**Fig. 1**) [7] has been upgraded to provide information about train locations. An Apple Watch*3 version has also been released. As we approach 2020, JR East App will continue to evolve to become an even more useful tool for more users. The data it will access will continue to grow. We will continue to maintain the current development organization in order to be able to better respond to customer requests in a timely manner.

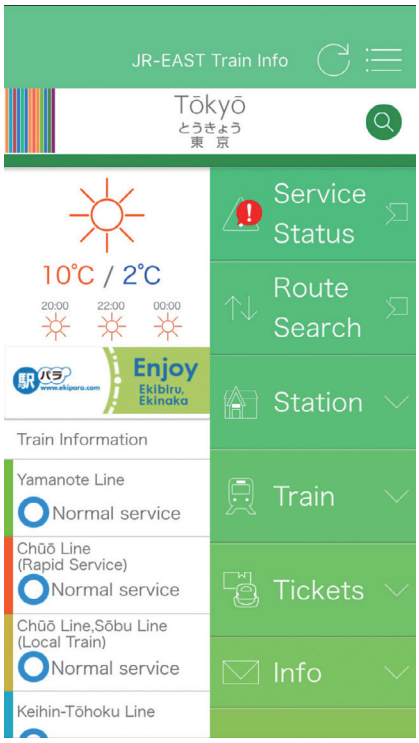


Fig. 1. Top page of the JR-EAST Train Info app.

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*3 Apple Watch is a trademark of Apple Inc., registered in the U.S. and other countries.

Takashi Ogawa
Chief Director, EnterPrise Business Department, NTT Software Corporation.

He received a B.E. in electrical engineering from Tokai University in 1991 and joined NTT Software the same year. Since then, he has been involved in developing the middleware of the Directory Integration Platform and has done security-based research and development. He also worked in the areas of system engineering, account sales, and transport systems.

*Takayuki Matsumoto is with East Japan Railway Company.

Pitarie: Picture Book Search with Interdisciplinary Approach

Takashi Hattori, Tessei Kobayashi, Sanae Fujita, Yuko Okumura, and Kazuo Aoyama

Abstract

NTT Communication Science Laboratories has developed a search system called Pitarie that can find just the right picture book to match a child's interests and developmental stage. Pitarie has been developed with an interdisciplinary approach; we incorporate knowledge of developmental psychology as well as the latest advances in the research fields of similarity search and natural language processing. The unique functions of Pitarie realized by the fusion of human science and information science are presented here along with the elemental technologies.

Keywords: picture book, search system, early childhood learning

1. Introduction

Children's language development is enhanced when their parents read picture books to them [1]. Many believe that reading stories with moral value to children, whether their endings are happy or sad, fosters the emotional development of children. Parents can expect that their children's language development and emotional education will be enhanced if they can find picture books that match their children's interests and developmental stages.

2. Finding picture books on the Internet

Using an Internet search engine makes it possible to find picture books by searching under authors or titles. Book reviews on the Internet provide information about how people felt about particular books. One can also look up recent picture book sales rankings on sites specializing in picture books by specifying factors such as age and gender. In addition, these sites recommend picture books to customers who purchase books regularly based on collaborative filtering; that is, the websites find groups of customers with similar purchase records and notify each customer of the books they have not yet purchased but that have been purchased by many other members of the group. Since people with similar purchase records are likely to have many of the same interests, the recommended books are likely to match the regularly purchasing customers' interests.

3. Ways of choosing picture books

Finding picture books on the Internet is common nowadays. However, a surprising result was obtained in a questionnaire we conducted at a large-scale picture book event called the Picture Book Museum held annually at the Fukuoka Asian Art Museum. We asked 770 parent-child pairs how they searched for or chose picture books, and only 188 pairs (24% of the total) answered that they had used the various methods available on the Internet. The most common answer, cited by 540 pairs (70% of the total), was that they had visited bookstores or libraries. That is, even though a great deal of information can be obtained from the Internet, many parents and children still choose the old-fashioned way of going to places where they were able to take a look at actual picture books.

4. Aim of Pitarie in searching picture books

We found that currently, it is not very common to

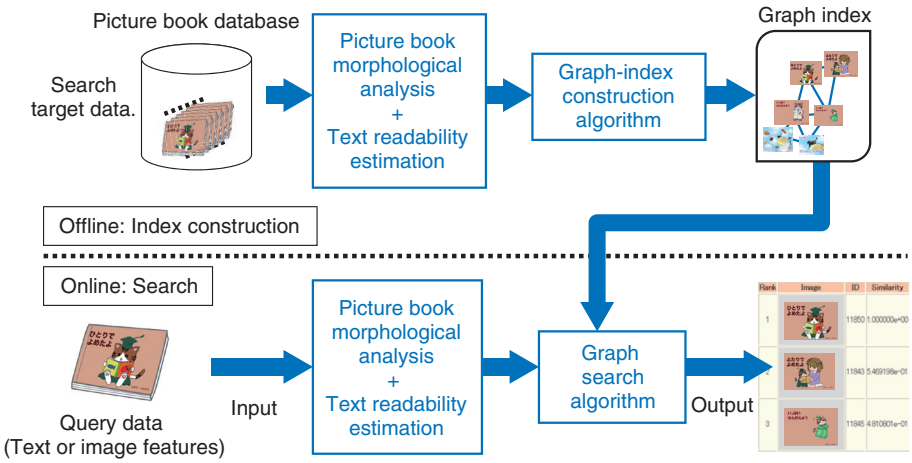


Fig. 1. Overview of Pitarie.

find picture books by using the existing methods on the Internet. At the same time, it can also be hard to find picture books in bookstores or libraries that have a limited number of books in stock. We developed Pitarie with the aim of overcoming these problems and finding picture books to suit children's interests and developmental stages. The system diagram of Pitarie is shown in **Fig. 1**.

5. Japanese picture book sentences—difficult for computers

In existing sites designed to help users find picture books, people typically search for book contents that are similar to those of another book they have read by classifying the book on the basis of its contents. This means that books can be categorized manually, but there are two problems; it is time consuming, and the categories are limited to pre-set categories. In contrast, Pitarie has a function to automatically analyze picture book sentences via natural language processing techniques for handling sentences. Note, however, that it is difficult to apply ordinary natural language processing techniques to picture book sentences. An interesting fact is that even though picture book sentences are easier for people to handle than those written for adults, they are harder for computers to handle.

This can be explained as follows. The first step in natural language processing of Japanese is morphological analysis, which involves dividing sentences into morphemes (words). Unlike written English, which is represented only by alphabetic characters (letters), written Japanese consists of various types of characters: hiragana, katakana, and kanji, that is, Chinese characters. Hiragana and katakana characters are phonograms, characters that represent sounds, and kanji characters are ideograms, or characters that represent meaning. Since there are far fewer variations of hiragana and katakana characters than there are kanji, and katakana is mainly used to represent foreign words, children learn hiragana first. As shown in **Fig. 2**, sentences written for adults usually combine a mixture of hiragana and kanji, and these characters serve as hints for morphological analysis. Kanji is especially helpful because it restricts the number of candidate morphemes. However, since picture book sentences are written almost entirely in hiragana, the characters cannot serve as hints, and morphological analysis becomes quite difficult.

Therefore, we have developed a morphological analyzer with high accuracy even for sentences written almost entirely in hiragana characters [2]. The analyzer automatically constructs a dictionary and learning data according to the characteristics of picture books. Pitarie uses the results of this morphological analyzer to estimate the readability of each book and to search books based on their contents.

6. Finding picture books of interest to the reader

We focused on two items as features of picture books: first, vocabulary used in the book and its appearance frequency, and second, bibliographic information such as the author's name. We considered that these were important in searching by focusing

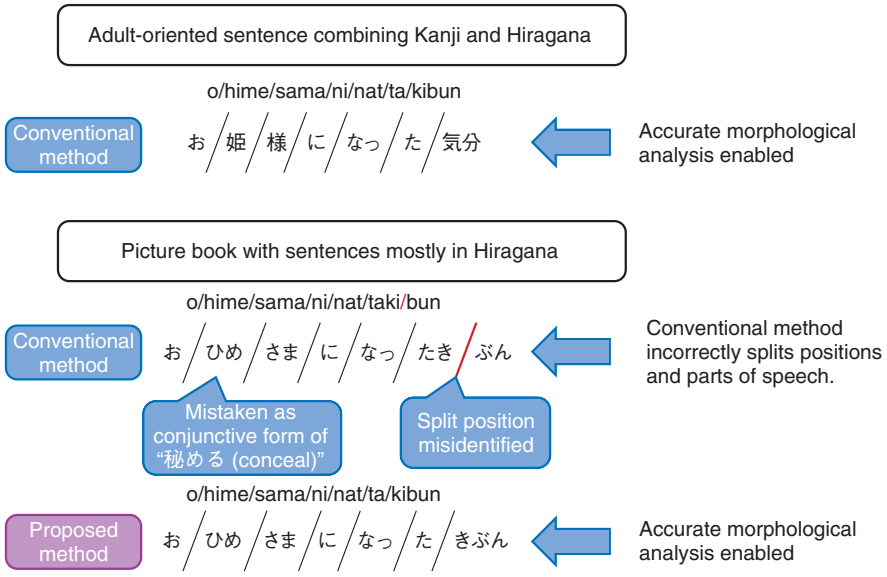


Fig. 2. Morphological analysis.

on the book's content. For example, books in which vehicles play an important part tend to have a lot of frequently appearing words related to vehicles, and certain authors tend to show a marked preference for stories with happy endings.

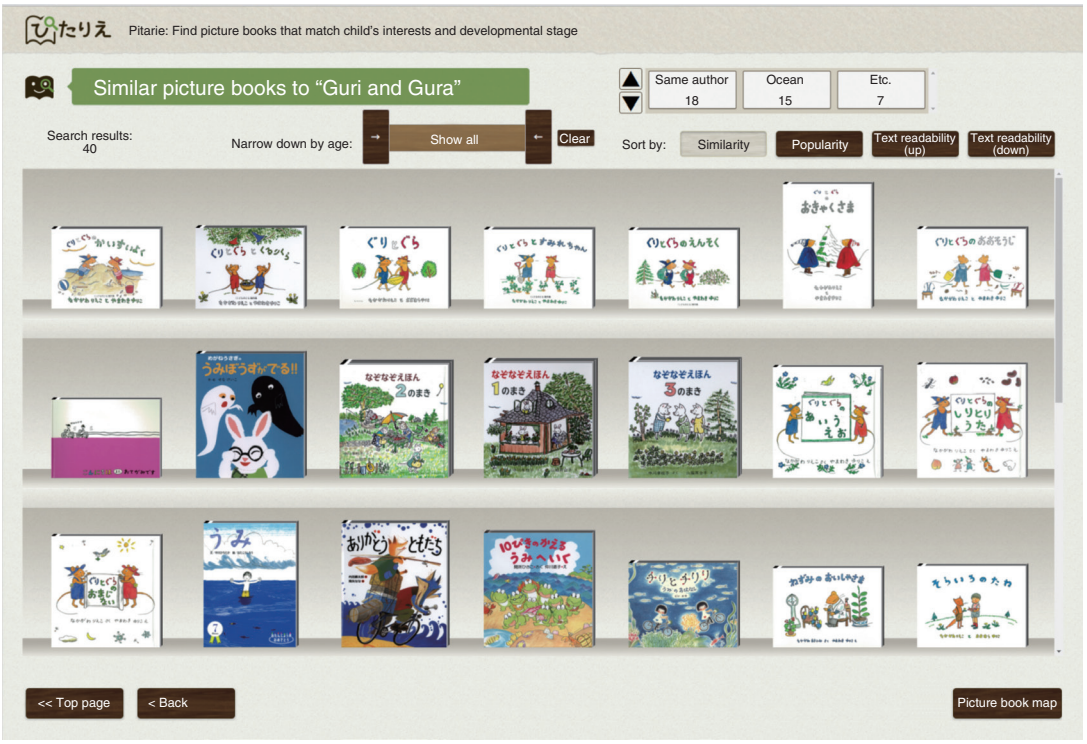
Pitarie performs similarity search using the above-mentioned features. Conventional picture book retrieval systems find books in which the information exactly coincides with a given small amount of information such as keywords. In contrast, similarity search attempts to satisfy as many conditions as possible for a large amount of input information. Precise searches are better when one knows precisely what one is looking for, for example, "The picture book titled '*Gon, the Little Fox*'" or "Books written by Nankichi Niimi." However, Pitarie works better when one does not know precisely what one is looking for. Pitarie makes it possible to search in ways that conventional systems find hard to handle, using inputs such as "I want to find a picture book that has a story line similar to that of my favorite picture book" and "I can't remember the title, but I'm looking for a picture book in which a family went on an outing to the sea and someone almost drowned."

The search results Pitarie produced for the input *Guri and Gura's Seaside Adventure* (Rieko Nakagawa (author) and Yuriko Yamawaki (illustrator), Fukuinkan Shoten Publishers, 1976) are shown in **Fig. 3**. In this case, a large number of text features were used as search items: 195 distinct words appearing in *Guri and Gura's Seaside Adventure*, their frequency, and five types of bibliographic information including the authors' names. The output results, obtained from the 2012 picture books in the Pitarie database, showed the books that had the most in common with the 200 text features. They included similar books written by the same authors with many words in common, for example, sea, swim, and swimming tube. A lot of information was entered, so the output results were based on a large number of features. As a result, a wide variety of picture books were found, and the books are similar to each other in many ways.

Pitarie also has a picture book map function (**Fig. 4**) that enables it to intuitively understand the complex search results. Pitarie achieves fast search with its graph-based similarity search algorithm, which utilizes as an index a graph (network) that is constructed by connecting similar picture books. The picture book map function displays the subgraph of the graph-based index that is related to the search results [3]. In the example shown in Fig. 4, the picture books are broadly divided into two groups that each consist of picture books sharing the same characteristics.

7. Finding picture books from the illustrations

The graph-based similarity algorithm is versatile since it is applicable to any data set where some kind of distance* is defined between the search target objects. Performing searches on the basis of similarities



*Information on the books shown here is given after the references section.

Fig. 3. Screenshot of Pitarie's search result.

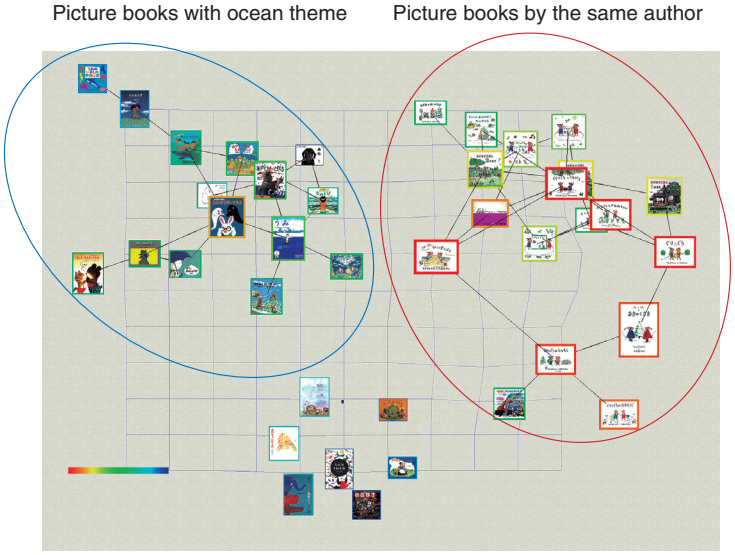


Fig. 4. Graphical visualization.

* To be precise, the "distance" may be a dissimilarity that does not fully satisfy the distance axiom.

between the illustrations in books allows people to find picture books whose illustrations are similar to

*Information on the books shown here is given after the references section.

Fig. 5. Similar illustration search.

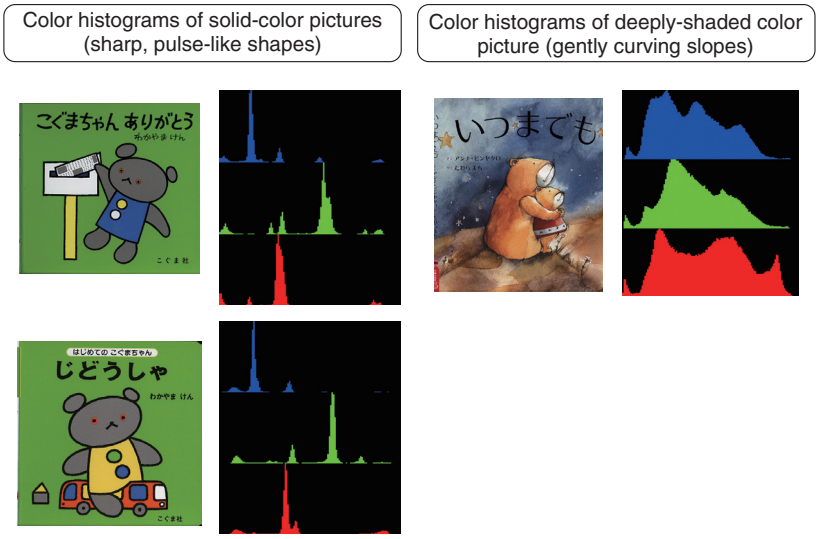
those in their favorite picture books. The results Pitarie produced in a search for picture books whose cover illustrations were similar to that of *There Are No Ghosts* (Keiko Sena, Poplar Publishing, 2009) are shown in **Fig. 5**.

Many kinds of features can be extracted from the illustrations. One example is color schemes. There are roughly two kinds of color schemes in picture books; a simple, solid color scheme and a gradational color scheme. We used an image feature to handle these schemes. The image feature we focused on was the distribution of colors in pictures (color histograms). The color histograms of solid-color pictures have sharp, pulse-like shapes, as shown in **Fig. 6**. In contrast, the color histograms of color pictures with considerable gradation take the form of gently curving slopes.

Another characteristic we adopted was the degree of detail in the illustrations. A technique called edge detection can be used to extract lines from pictures (**Fig. 7**). Complex pictures with a great amount of detail have a proportionately large number of lines, while the number is much smaller in simple pictures illustrated as cartoons. By observing how the lines are distributed in the picture area, we can determine whether the illustration is drawn in a general, overall manner, or one in which the focus is on a certain character or other object. In this way, using the multiple features of illustrations in combination with each other makes it possible to search for particular picture books or for other books whose illustrations show the same features or characteristics.

8. Finding picture books to match developmental stage

Some publishers include information about the target age the book is intended for in their picture books. This information provided by professionals is useful for choosing picture books for children at certain ages. However, an investigation of over 2000 books (primarily best sellers) revealed that less than half of picture books contained this information. Furthermore, much of the information is somewhat ambiguous or overly broad in scope, with statements such as “Recommended for infants” or “Recommended for children 1–3 years of age.” On top of this, choosing books to match the developmental stage solely on the



*Information on the books shown here is given after the references section.

Fig. 6. Color histograms of picture book cover-fronts.

Fig. 7. Edge detection obtained with Canny method.

basis of the recommended target age information may not be a particularly effective approach. This is because children learn new words very quickly, and so those approaching their 3rd birthday will generally have a much larger vocabulary than those who have just celebrated their 2nd, although both can be said to be two years old.

Therefore, we have developed a method for estimating the readability (target age) of picture books. It combines knowledge of developmental psychology and techniques used in natural language processing. In studying child language development from the viewpoint of developmental psychology, we are focusing in particular on clarifying the mechanism through which children acquire their vocabulary. In this we received the cooperation of over 3000 parent-child pairs, enabling us to compile data on what words the children learned and spoke at what age [4]. The individual differences we found in vocabulary acquisition were not inconsiderable, but performing logistic regression with the obtained data enabled us to accurately determine the time frame in which words were learned and spoken for about half of the children surveyed.

In developing the method, we used the data obtained on vocabulary acquisition time as well as the sentence characteristics (such as length) publishers used to determine the age groups for which picture books were targeted [5]. People using the method will be able to estimate the targeted age group even if the publisher has not provided it. They will also be able to rank picture books having the same target age information in order of reading ease, or find picture books similar to others they have read and enjoyed. By incorporating this method, Pitarie makes it possible for parents to find picture books to match their children's developmental stage with greater accuracy than could be obtained before.

9. Future development

In this article, we described the picture book search system Pitarie that we developed to find picture books that best match children's interests and developmental stages. Pitarie utilizes the latest methods in information science and incorporates knowledge of human science in searching for picture books. Its advanced functionality enables it to perform functions that conventional picture book retrieval systems cannot easily perform. These functions are as follows: searching for picture books that have the same topic or have a similar style of illustration as one's favorite picture book; searching for picture books on the basis of one's vague memory by typing in the rough story; and estimating the text readability of books whose target age groups are not specified by publishers.

In the future, we plan to conduct practical experiments with Pitarie in libraries. The experiments will enable us to grasp any existing problems via the information collected from many pairs of parents and children. They will also make it possible to further clarify the aims we are striving to achieve, so that we can develop a new system version with even better capabilities. We will also attempt to further improve the graph-based index similarity search function, the natural language processing function, and other functions that make up the Pitarie system.

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Picture books shown in Fig. 3

Top row (from left):

Guri and Gura's Seaside Adventure, Rieko Nakagawa (author) and Yuriko Yamawaki (illustrator), Fukuinkan Shoten Publishers, 1977 (Japanese edition).

Guri and Gura's Magical Friend, Rieko Nakagawa (author) and Yuriko Yamawaki (illustrator), Fukuinkan Shoten Publishers, 1992 (Japanese edition).

Guri and Gura, Rieko Nakagawa (author) and Yuriko Omura (illustrator), Fukuinkan Shoten Publishers, 1967 (Japanese edition).

Guri and Gura's Special Gift, Rieko Nakagawa (author) and Yuriko Yamawaki (illustrator), Fukuinkan Shoten Publishers, 2003 (Japanese edition).

Guri and Gura's Picnic Adventure, Rieko Nakagawa (author) and Yuriko Yamawaki (illustrator), Fukuinkan Shoten Publishers, 1983 (Japanese edition).

Guri and Gura's Surprise Visitor, Rieko Nakagawa (author) and Yuriko Yamawaki (illustrator), Fukuinkan Shoten Publishers, 1967 (Japanese edition).

Guri and Gura's Spring Cleaning, Rieko Nakagawa (author) and Yuriko Yamawaki (illustrator), Fukuinkan Shoten Publishers, 2002 (Japanese edition).

Middle row (from left):

Konnichiwa Mata Otegami Desu, Rieko Nakagawa (author) and Yuriko Yamawaki (illustrator), Fukuinkan Shoten Publishers, 2014 (in Japanese).

Megane Usagi no Umibozu ga Deru, Keiko Sena (author and illustrator), Poplar Publishing, 2005 (in Japanese).

Nazonazo Ehon 2 no Maki, Rieko Nakagawa (author) and Yuriko Yamawaki (illustrator), Fukuinkan Shoten Publishers, 1988 (in Japanese).

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Guri and Gura's AIUEO, Rieko Nakagawa (author) and Yuriko Yamawaki (illustrator), Fukuinkan Shoten Publishers, 2002 (Japanese edition).

Guri to Gura no Shiritoriuta, Rieko Nakagawa (author) and Yuriko Yamawaki (illustrator), Fukuinkan Shoten Publishers, 2009 (in Japanese).

Bottom row (from left):

Guri to Gura no Omajinai, Rieko Nakagawa (author) and Yuriko Yamawaki (illustrator), Fukuinkan Shoten Publishers, 2009 (in Japanese).

Umi, Hirotaka Nakagawa (author) and Koshiro Hata (illustrator), Jiyukokuminsha, 2011 (in Japanese).

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Dr. Mouse's Mission, Masafumi Nakagawa (author) and Yuriko Yamawaki (illustrator), Fukuinkan Shoten Publishers, 1977 (Japanese edition).

The Sky Blue Seed, Rieko Nakagawa (author) and Yuriko Omura (illustrator), Fukuinkan Shoten Publishers, 1967 (Japanese edition).

Picture books shown in Fig. 5

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Megane Usagi, Keiko Sena (author and illustrator), Poplar Publishing, 1975 (in Japanese).
Bunbun Kiiro, Akio Kashiwara (author and illustrator), Gakken Plus, 2010 (in Japanese).
Kuishinbo Usagi, Keiko Sena (author and illustrator), Poplar Publishing, 2004 (in Japanese).
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Yasai no Onaka, Katsu Kiuchi (author and illustrator), Fukuinkan Shoten Publishers, 1997 (in Japanese).
Megane Usagi no Umibozu ga Deru!!, Keiko Sena (author and illustrator), Poplar Publishing, 2005 (in Japanese).
Aka Aka Kuro Kuro, Akio Kashiwara (author and illustrator), Gakken Plus, 2010 (in Japanese).
Kudamono Nanda, Katsu Kiuchi (author and illustrator), Fukuinkan Shoten Publishers, 2007 (in Japanese).
Kongaragacchi - Docchi ni Susumu? no Hon, Euphrates (author and illustrator), Shogakukan, 2009 (in Japanese).

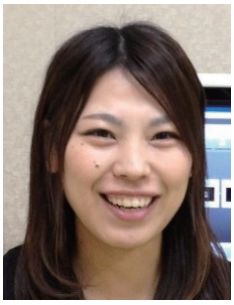
Picture books shown in Fig. 6

Koguma-chan, Arigato, Ken Wakayama (author and illustrator), Koguma Publishing, 1972 (in Japanese).
Jidosha, Ken Wakayama (author and illustrator), Koguma Publishing, 1994 (in Japanese).
Itsumademo, Anna Pignataro (author and illustrator), Machi Tawara (translator), Shufunotomo, 2007 (Japanese edition).

Takashi Hattori
Research Scientist, Learning and Intelligent Systems Research Group, Innovative Communication Laboratory, NTT Communication Science Laboratories.
He received an M.S. in informatics from Kyoto University in 2004. He joined NTT Communication Science Laboratories in 2004. He is currently interested in fast approximate similarity search for various large-scale media.

Tessei Kobayashi
Senior Research Scientist (Distinguished Researcher), Interaction Research Group, Innovative Communication Laboratory, NTT Communication Science Laboratories.
He received a Ph.D. in psychology from the University of Tokyo in 2004. He is currently researching child language development, especially vocabulary spurts and syntactic bootstrapping.

Sanae Fujita
Research Scientist, Linguistic Intelligence Research Group, Innovative Communication Laboratory, NTT Communication Science Laboratories.
She received a Ph.D. in engineering from Nara Institute of Science and Technology in 2009. She is currently researching natural language processing, especially word disambiguation and text readability estimation.



Yuko Okumura
Research Associate, Interaction Research Group, Innovative Communication Laboratory, NTT Communication Science Laboratories.
She received a Ph.D. in psychology from Kyoto University in 2014. She is currently conducting research on social cognition and language development in young children.

Kazuo Aoyama
Senior Research Scientist, Learning and Intelligent Systems Research Group, Innovative Communication Laboratory, NTT Communication Science Laboratories.
He received an M.E. from Tokyo Institute of Technology in 1988. He joined NTT in 1988 and worked on device modeling of various types of metal-oxide-semiconductor field-effect transistors for circuit simulation and studied reconfigurable computer architectures and circuit design methodology. He is currently researching data structures and algorithms. He is a member of the Institute of Electrical and Electronics Engineers, the Institute of Electronics, Information and Communication Engineers, the Information Processing Society of Japan, and the Japan Society of Applied Physics.

Move&Flick: Text Input Application for Visually Impaired People—From Research and Development to Distribution of the Application

Ryosuke Aoki, Ryo Hashimoto, Misa Hirao, Masahiro Watanabe, Tomohiro Yamada, Kazuma Ito, Akihito Tanaka, Tomoaki Kodaka, Akihiro Ohtsu, Akihiko Sasaki, Yukio Takayashiki, and Mitsutoshi Ehara

Abstract

Move&Flick is a new text input application on smartphones developed by NTT DOCOMO. The application is designed for visually impaired people and has been available on Apple's App Store since August 2015. NTT Service Evolution Laboratories researched and developed the algorithms to recognize finger motions that are used to operate the application, as well as the application's basic design, together with NTT CLARUTY, some of whose employees are visually impaired. NTT DOCOMO developed the application based on Apple's App Store Review Guidelines and has been working with NTT CLARUTY to support visually impaired users so that they benefit sufficiently from the application. This article introduces the process from research and development to the distribution of the application on Apple's App Store.

Keywords: visually impaired, text input, touch screen

1. Introduction

Many visually impaired people are interested in smartphones with touch screens since more smartphone applications are becoming available that are designed for such users, and some users are highly motivated to use devices that have become popular with many people. However, smartphone applications that demand a lot of text input via touch screens pose a challenge for the visually impaired. It is difficult to input text using the standard touch operation providing voice feedback that is similar to the key operation used with the numeric keyboards for feature phones, as the touch screens have no surface indentations.

Voice input is standard in smartphones and can be very helpful for people with visual impairments. However, this input is difficult to use in public spaces such as trains or department stores, as visually impaired users are reluctant to provide revealing details that people nearby, who are strangers, can hear.

While fluency in the standard operation of smartphones can be acquired with long-term training, most visually impaired people continue to use feature phones due to their ease of use, or they use a feature phone for text input and a smartphone for other applications. There has long been a demand for a new text input interface/application for smartphones that is easy to learn and to use by visually impaired users.

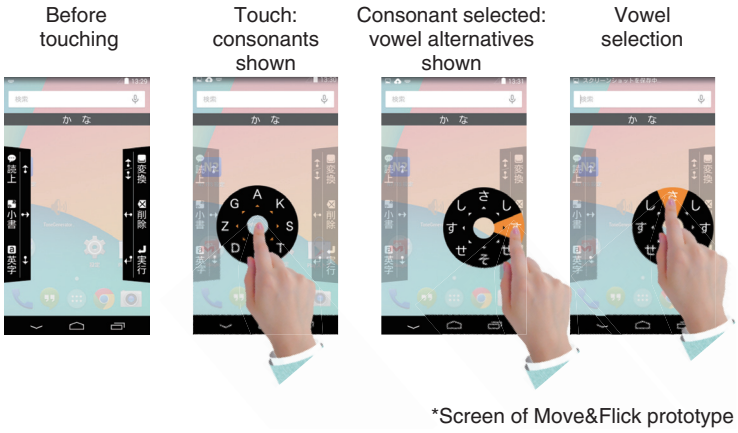


Fig. 1. Basic gestures of Move&Flick.

2. Easy-to-acquire gestures on touch screens for visually impaired people

NTT Service Evolution Laboratories has been researching and developing a new text input method for smartphone screens for visually impaired users. To ensure practicality, we focused on single finger gestures on the screen and attempted to minimize the importance of touch positions on the screen. Of course, multi-touch operations do exist and are already used in various applications. However, there is a lack of commonality, meaning that the same gestures can yield different commands depending on the application, and this tends to confuse the visually impaired. This is a unique problem for multi-touch gestures.

We asked the visually impaired staff of NTT CLARUTY to try various single finger gestures for screen input and identified which gestures were easy for the visually impaired to acquire. It is clearly difficult for visually impaired users to learn complicated gestures such as ideograms, as the lack of visual feedback means that they cannot understand what errors were made and how to correct them, and voice feedback makes it difficult for users to understand what errors were made and how to correct them. Even with an encircling gesture, which most people assume to be fairly simple, the finger of the visually impaired person tended to hit the side of the screen. Our investigation showed that they were able to acquire a gesture consisting of two continuous finger strokes with no intermediate finger lift; each stroke was made in one of eight directions, as shown in **Fig. 1**. The first stroke selects a consonant (or a command group), and the second stroke selects a vowel (or a command of the selected group). A Japanese character is input as combinations of a consonant and a vowel. The name *Move&Flick* replicates the basic gestures.

3. Techniques to facilitate learning the basic gestures of Move&Flick

Move&Flick is designed to help visually impaired users acquire the gestures with high accuracy and to increase the recognition accuracy of the basic gestures. Move&Flick has an algorithm to detect finger movement direction using radial areas with dead zones, as shown in **Fig. 2**. The finger movement direction is selected when a finger moves from the circle area into any of the eight radial areas. The selected area is provided as feedback to the user by voice. No movement direction is output while the finger is in the circle area or dead zones. This design helps the visually impaired to understand the ideal finger movement directions and to easily acquire the basic gestures. In addition, the dead zones suppress detection errors even if the operation is rough and quick, as may be expected with more experienced users.

Move&Flick also has an algorithm to accurately detect the change point, which is when the first stroke changes to the second stroke. This is necessary because the distance of finger movements differs with each input of each person, and the accuracy with which the change point is detected affects the accuracy with which the second stroke is detected. The details of this algorithm are shown in **Fig. 3**. The change point is Point Y, and the point at which the

The dead zones drive the voice feedback used to help the visually impaired learn the method and acquire the eight finger directions with a high degree of accuracy. The dead zones also minimize errors when the users become familiar with Move&Flick operation and facilitate more casual but rapid finger motions.

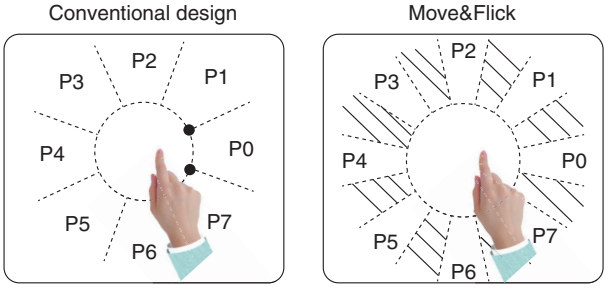
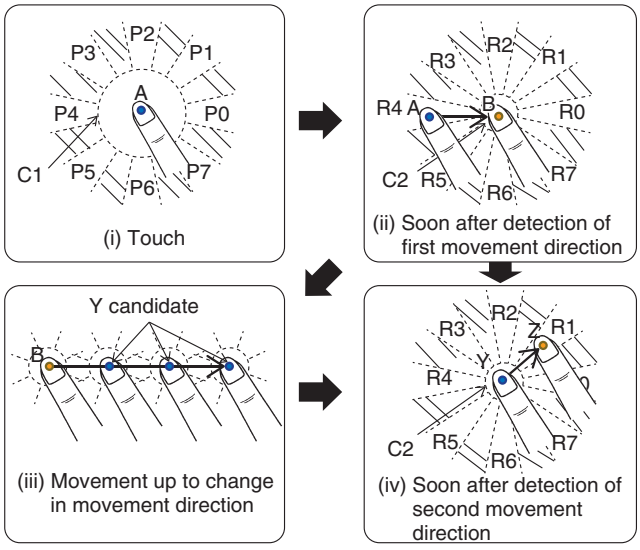


Fig. 2. Algorithm to detect movement direction based on radial areas with dead zones.

Move&Flick's algorithm can precisely detect the change point between the first movement direction and the second movement direction.



A: Touch point; B: First finger point over C1;
Y: Direction change point; Z: Release point

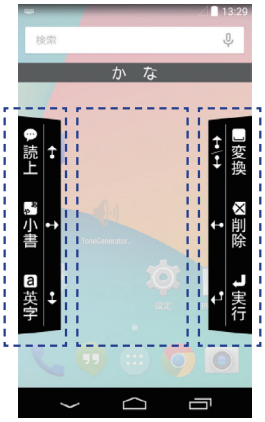
Fig. 3. Algorithm to detect the change point from first movement direction to second movement direction.

first stroke direction is detected is Point B, which does not coincide with Point Y. The algorithm confirms whether the detected first stroke direction and the direction of the finger motion is the same every time the finger moves a prescribed distance, which is the radius of C2 shown in Figs. 3(ii) and 3(iv), and sets Point Y when the first stroke direction and the direction of finger motion are different. The algorithm reduces the need to be careful about moving the finger the correct distance.

NTT Service Evolution Laboratories developed these algorithms as part of a project organized by the Ministry of Internal Affairs and Communications in the Japanese Government.

4. Design of Move&Flick

Japanese text input applications for the visually impaired include not only characters but also options such as delete, kana-kanji transformation, and options



• Center area of the screen
The area for character input

• Left area of the screen
Voice reader • Small capitals • Change character type.

• Right area of the screen
Transform • Delete • Enter

*Screen of Move&Flick prototype

Fig. 4. Three screen areas are easily selected.

such as a voice reader. Various studies have been done on text input, but few text input applications have been released that implement the research achievements. One reason is that the application designs failed to implement all required commands.

Japanese characters outnumber alphanumeric characters, and there are several operations such as kana-kanji transformation and kana-katakana transformation that alphabet text input applications do not have. Therefore, NTT Service Evolution Laboratories in conjunction with NTT CLARUTY worked on enhancing the basic gestures of Move&Flick to simplify the input of all commands and effectively map gestures to commands.

To increase the level of modality, we focused on motions before the basic gestures. We implemented a means of changing the mode of input by entering a single tap immediately before entering the basic gestures. Most of the visually impaired users were able to learn this single tap operation in a short time. The operation in Move&Flick is used to change the consonant.

We also examined how the smartphones were held. The visually impaired tend to hold the smartphone with the non-dominant hand and operate the device with the dominant hand. Visually impaired users can discern the device width since smartphones have touch screens that are basically as wide as the device and the non-dominant hand has physical contact with both sides of the device. Therefore, they can accurately touch the left and right areas, each of which has the width of a single finger (**Fig. 4**). To input a character, the basic gestures are performed after touching the center area. To input an option, the basic gestures are performed after touching the left or right area.

The mapping of gestures to commands must be easy to remember if the visually impaired are to learn how to operate Move&Flick. NTT Service Evolution Laboratories and NTT CLARUTY carefully refined the assignment of consonants and vowels and the classification of option commands. Since some visually impaired people are already familiar with smartphones such as iPhones*, the mapping was made as universal as possible to avoid confusion. NTT Service Evolution Laboratories had the visually impaired staff of NTT CLARUTY check each mapping change. Thus, Move&Flick was designed using a human-centered approach.

5. Experiment to evaluate the Move&Flick design

NTT Service Evolution Laboratories conducted an experiment to evaluate whether subjects were able to input kanji using Move&Flick after one hour of instruction and training. All subjects were visually impaired, and half of them had prior experience in operating smartphones. The results showed that all subjects were able to input kanji. Those experienced in the use of smartphones indicated that they wanted to use Move&Flick. Of the subjects without any experience in using smartphones, 60% also stated their desire to use Move&Flick. These results confirmed the feasibility of Move&Flick as an application for visually impaired users.

* iPhone is a trademark of Apple Inc., registered in the U.S. and other countries.

6. Preparation for application distribution

NTT DOCOMO developed Move&Flick for distribution based on the technical specifications provided by NTT Service Evolution Laboratories. Because visually impaired users tend to prefer the iPhone, the application program was written to ensure compliance with App Store Review Guidelines. In addition, NTT DOCOMO, together with NTT CLARUTY and a software vendor, improved the application based on the opinions of visually impaired people obtained in a survey. Some key steps in the development are given below.

- Built-in Japanese dictionary software was added to the application.
- A function to change the software keyboard was added to the application.
- A function to freely adjust the voice reader speed was added.
- The operability of the application was improved.

7. Introduction of Move&Flick for the visually impaired

NTT DOCOMO advertised Move&Flick on its website, and NTT CLARUTY advertised Move&Flick in mailing lists and in communities for the visually impaired. NTT DOCOMO also held a trial session at the docomo Lounge, its main showroom in the Marunouchi area of Tokyo, to let a lot of visually impaired people know about Move&Flick, which is a new concept of text input appropriate for people with all levels of visual impairment. Visually impaired people and media representatives attending the session were able to try out Move&Flick. An NTT CLARUTY staff member served as a guide and introduced Move&Flick to the participants as a useful application enabling the visually impaired to input text on a touch screen.

NTT DOCOMO, together with NTT CLARUTY, has published audio manuals for Move&Flick based on the Digital Audio-based Information System format so that visually impaired users can learn how to use Move&Flick by themselves. In addition, the company provides a mock-up of Move&Flick (**Fig. 5**) to help users understand the operation of Move&Flick at docomo Hearty Plaza Marunouchi, a space dedicated to helping all users, including the visually impaired, how to use mobile devices. These mock-ups of Move&Flick have also been used at various exhibitions for NTT DOCOMO staff to show them how to use Move&Flick.

Fig. 5. Application mock-up.

8. Future prospects

NTT DOCOMO is proposing Move&Flick as a new text input application for the visually impaired. Various improvements have already been made to Move&Flick based on feedback and comments received from visually impaired users. While there are several existing smartphone applications that attempt to support the visually impaired, their acceptance is weak due to handicaps in their use. NTT DOCOMO will continue to strive to support the visually impaired with the goal of enabling them to fully enjoy their daily lives.

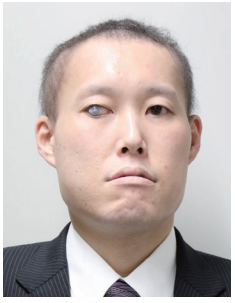
Ryosuke Aoki
Researcher, Networked Robot and Gadget Project, NTT Service Evolution Laboratories.
He received a B.E. in engineering and an M.S. and Ph.D. in information sciences from Tohoku University, Miyagi, in 2005, 2007, and 2014. Since joining NTT in 2007, he has been conducting research in the areas of human computer interaction, multimodal interaction, motor learning, and service design. He has been a Visiting Assistant Professor at Tokyo Denki University since April 2016.

Ryo Hashimoto
Researcher, Universal UX Design Project, NTT Service Evolution Laboratories.
He received a B.E. in engineering and an M.E. in informatics from Kyoto University in 2008 and 2010. Since joining NTT in 2010, he has been studying human computer interaction, universal design, and instructional design. He is a member of the Institute of Electronics, Information and Communication Engineers (IEICE).

Misa Hirao
Researcher, Universal UX Design Project, NTT Service Evolution Laboratories.
She received a B.A. in policy management in 2008 and a Master of Media and Governance in 2010 from Keio University, Kanagawa. She joined NTT Cyber Solution Laboratories in 2010, where she has been studying human-computer interaction, especially universal design and user-centered design.

Masahiro Watanabe
Senior Research Engineer, Universal UX Design Project, NTT Service Evolution Laboratories.
He received a B.E. and M.E. in mechanical engineering and a Dr.E. in electronics, information, and communication engineering from Waseda University, Tokyo, in 1991, 1993, and 2003. He joined NTT Basic Research Laboratories in 1993 and studied the human auditory system. Since moving to NTT Cyber Solutions Laboratories in 1999, he has been studying human-computer interaction, especially universal design and user-centered design. He is a member of IEICE, the Human Interface Society, and the Acoustical Society of Japan.

Tomohiro Yamada
Executive Research Engineer, Supervisor, Networked Robot and Gadget Project, NTT Service Evolution Laboratories.
He received an M.S. in electronics engineering from Niigata University in 1992 and an MBA from the University of Birmingham, UK, in 2007. He joined NTT in 1992, where he has been researching content distribution systems and technologies to support home appliances. He is the W3C (World Wide Web Consortium) Advisory Committee Representative of NTT and also a member of the Association for Computing Machinery, the Institute of Electrical and Electronics Engineers, and the Information Processing Society of Japan.



Kazuma Ito
Assistant Manager, Accessibility Promotion Office, Sales Department, NTT CLARUTY CORPORATION.
He graduated from the Department of Management and Information Science from Niigata University of Management in 2003. He completed a course at the National Vocational Rehabilitation Center for Persons with Disabilities in 2005, after which he joined NTT CLARUTY. He has been working on improving web accessibility for persons with disabilities and developing barrier-free products and services.

Akihito Tanaka
Associate Manager, Accessibility Promotion Office, Sales Department, NTT CLARUTY CORPORATION.
He graduated from the Faculty of Informatics, Department of Computer Science, Shizuoka University, in 2001. He worked at a company where he developed information systems from 2001 to 2003. He completed a course at the National Vocational Rehabilitation Center for Persons with Disabilities in 2004 and joined NTT CLARUTY the same year. He has been engaged in improving web accessibility for persons with disabilities and supporting the development of barrier-free products and services.

Tomoaki Kodaka
Manager, Accessibility Promotion Office, Sales Department, NTT CLARUTY CORPORATION.
He graduated from the Aoyama Gakuin University Faculty of Law in 1987. From 1987 through 2002, he worked for Japan Finance Corporation. Since joining NTT CLARUTY in 2004, He has been engaged in managing efforts to evaluate and verify the accessibility of products and services to achieve universal design.

Akihiro Ohtsu
Senior Vice President, Executive Manager, Sales Department, NTT CLARUTY CORPORATION.
He joined NTT in 1981. He was on loan to NTT CLARUTY from NTT EAST in 2012. He has been engaged in driving employment for persons with disabilities, increasing market sales, and negotiating with other companies including NTT Group companies.

Akihiko Sasaki
NTT DOCOMO, INC.
He joined NTT DOCOMO in 1998. He has been involved in developing smartphone applications and user interfaces designed for visually impaired users, specifically the Move&Flick application.

Yukio Takayashiki
FUJITSU LIMITED.
He was temporarily transferred to NTT DOCOMO in 2012, where he worked on the development of Move&Flick and mail applications such as docomo mail. He is now engaged in developing software for the Internet of Things at Fujitsu.

Mitsutoshi Ehara
NTT DOCOMO, INC.
He joined NTT DOCOMO in 1998. He has been developing character input operations in the Move&Flick smartphone application for visually impaired users.

G.fast Ultrafast Access Technology Standardization in ITU-T

Yoshihiro Kondo

Abstract

The International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) Study Group 15 (SG15) is the largest Study Group in ITU-T and has been working on the standardization of various issues in transport networks and telecommunication infrastructures, which cover transport technologies in home networks, access networks, packet transport networks, and optical transport networks as well as optical fiber cables. This article explains the latest metallic access technology called G.fast, one of the newest and most active technologies being examined for standardization in SG15. G.fast technology is classified as DSL (digital subscriber line) technology, with which an ultrafast transmission rate of 1 Gbit/s would be available for various services in access networks over metallic cables.

Keywords: G.fast, DSL, ITU-T

1. Introduction

This article introduces the ultrafast digital subscriber line (DSL) technology called G.fast, which is the newest standardization topic to be studied in Question 4 of the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) Study Group 15 (SG15). Question 4 concerns the development of standards for broadband access technologies over metallic conductors. SG15 started its work on DSL technologies in 1998, with its first ITU-T DSL-related Recommendation for high-bit-rate DSL (HDSL) technology being finalized in October 1998. That Recommendation covered private-line HDSL 2-Mbit/s and 1.5-Mbit/s services. Following this initial work, several Recommendations were developed under Question 4 up until 2010 based on such technologies as asymmetric DSL (ADSL), very high speed DSL (VDSL), and VDSL with vectoring functionality in order to provide improved Internet access services for public use; these are listed in **Table 1**. These standardization activities together with the development of relevant faster transmission technologies have been a strong driving force in the introduction of broadband Internet services in Japan.

It is worth mentioning that more than 10 million ADSL subscriber lines have been deployed in Japan, and more than 4 million VDSL subscriber lines have been installed in apartment buildings. It should be noted that a great demand for optical broadband access has been driven by this VDSL technology in FTTB (fiber-to-the-building) applications.

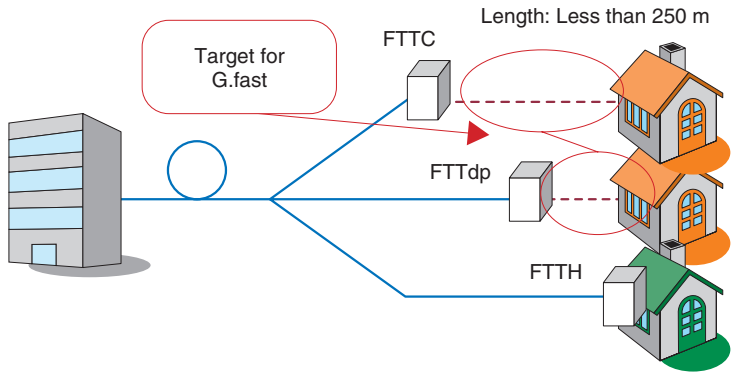
The G.fast standardization project started in December 2010 when ITU-T received a liaison letter from the Broadband Forum (BBF). The liaison letter drew attention to two things; the first was that the BBF planned to produce a white paper describing a set of broadband requirements based on requests from carriers deploying FTTC (fiber to the curb) and fiber to the distribution point (FTTdp), and the second was to ask ITU-T to develop relevant Recommendations that would satisfy the carriers' requests. After receiving this request from the BBF, ITU-T decided to start detailed studies under Question 4 in February 2011.

These G.fast studies cover those requirements issued by multiple carriers within the BBF targeting the areas shown in **Fig. 1**. G.fast technology will involve transmission technology over a distance of up

Table 1. Standards of metallic access technologies.

Technology	Standard	Yr. approved	Data rate	Applications
HDSL	G.991.1	1998	2048 kbit/s	1.5–2 Mbit/s symmetrical service
SHDSL	G.991.2	2001	768 kbit/s	HDSL on a single pair
ADSL	G.992.1	1999	6 Mbit/s / 640 kbit/s	Internet access, multimedia database access, and video distribution
ADSL2	G.992.3	2002	8 Mbit/s / 800 kbit/s	
ADSL2+	G.992.5	2003	16 Mbit/s / 800 kbit/s	
VDSL	G.993.1	2004	52 Mbit/s / 2.3 Mbit/s	Internet access, HDTV service
VDSL2	G.993.2	2006	100 Mbit/s	Internet access, HDTV service over longer loops with more users than VDSL
VDSL2 vectoring	G.993.5	2010	200 Mbit/s	
G.fast	G.9701	2014	1000 Mbit/s	Internet access, 4K TV service

HDTV: high-definition television
SHDSL: single-pair high-speed DSL



FTTH: fiber to the home

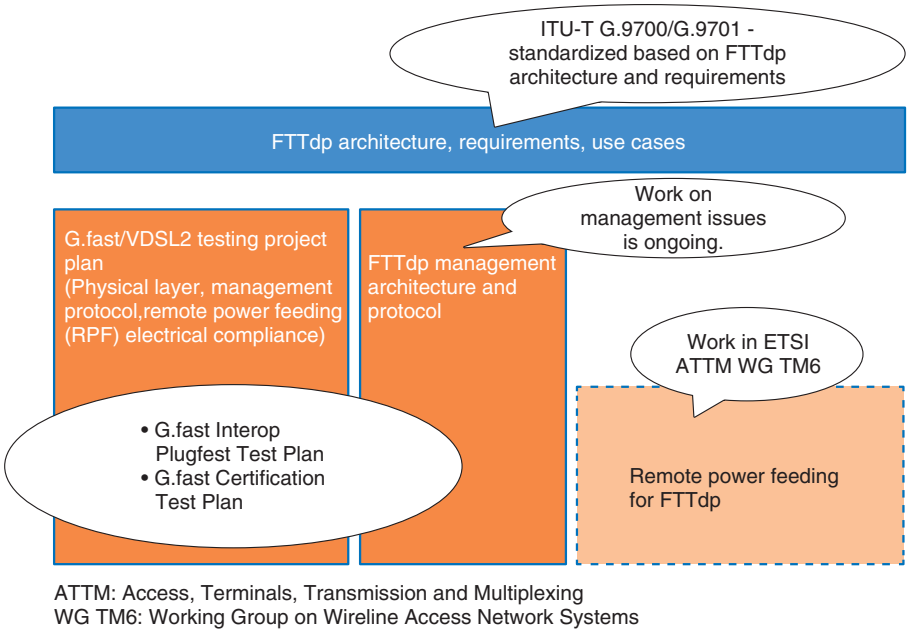
Fig. 1. Configurations of access networks: FTTH, FTTdp, and FTTC.

to around 250 m from distribution points where optical transmission is terminated so that subscribers can enjoy ultrafast broadband Internet access services of 1 Gbit/s aggregated (upstream and downstream) transmission rates using existing metallic cables.

The FTTdp project has been coordinated by the standards bodies indicated in **Fig. 2**. As explained above, the BBF initiated the project to consider use cases, corresponding requirements, and the necessary architectures, while ITU-T SG15 has been studying the detailed mechanisms and protocols of G.fast. At the same time, ETSI (European Telecommunication Standards Institute) has begun studying the remote power feeding functionality that would be supplied by remote subscribers. At present, the main concerns of the BBF are various specifications concerning interoperability and conformance tests so that FTTdp systems under development can be deployed commercially in the field.

2. Detailed technical specifications and G.fast standardization activities in ITU-T

The standardization work has been led by major carriers such as AT&T Inc., BT Group plc, Orange S.A., and Swisscom AG, all of which are the original promoters of this technology. The carriers made their requirements clear, enabling system vendors and chip vendors to develop detailed specifications satisfying carriers' requirements and implementing them into



ATTM: Access, Terminals, Transmission and Multiplexing
WG TM6: Working Group on Wireline Access Network Systems

Fig. 2. Overview of FTTdp project in the BBF.

the Recommendations.

2.1 Main characteristics of G.fast

(1) Ultrafast broadband access system over existing metallic cables
(2) Transmission rate of 1 Gbit/s between ONU (optical network unit) that terminates optical fiber and customer premises equipment (CPE)
(3) Specifications relevant to regulations such as frequency and power spectral density (PSD) described in ITU-T Recommendation G.9700
(4) Physical specifications described in ITU-T Recommendation G.9701
(5) Targeted downstream and upstream aggregated transmission rates:
- 500–1000 Mbit/s for cable length less than 100 m
- 200 Mbit/s for cable length of 200 m
- 50 Mbit/s for cable length of 250 m

To achieve the above features, the following core technologies have been implemented:

1) Time division duplex (TDD) multiplexing of downstream and upstream signal transmissions with frequencies as high as 212 MHz. Initially, however, 106 MHz is being utilized. This is different from VDSL, which uses FDD (frequency division duplex) multiplexing of downstream and upstream signal transmissions with frequencies up to 30 MHz.
2) Orthogonal frequency division multiplexing (OFDM) modulation, which is also used in VDSL

2.2 Vectoring functionality

G.fast is considered to be a next generation DSL technology and includes all the functionalities that VDSL provides, including vectoring, which facilitates mitigation of interference caused by far-end crosstalk (FEXT) noise from neighboring cables. The vectoring functionality requires some explanation. Although there are no systems in operation with this vectoring functionality in Japan, there are many carriers in North America and Europe that are deploying systems commercially with the vectoring functionality. Compared with ADSL systems, which are typically used to transmit signals from a telephone central office to CPE installed in subscribers' homes that are located up to a few kilometers away, VDSL systems tend to suffer from strong interference from neighboring lines. VDSL systems were developed to cover areas in which the cable length is less than or equal to about 1 km and to provide services with higher transmission rates than ADSL systems. VDSL is typically considered to be applicable to apartment buildings. Because of these requirements, VDSL systems suffer a lot of interference in the form of FEXT noise from

Table 2. Comparison between G.fast and VDSL2.

Item	ComVDSL2	G.fast
Frequency range	Up to 30 MHz	• 2–106 MHz • 2–212 MHz (planned)
Max rate	• 250 Mbit/s (30a), 150 Mbit/s (17a) • 30–80 Mbit/s in the field	• 1 Gbit/s (Less than 100 m) • 500 Mbit/s or more (100 m)
Modulation	OFDM	OFDM
Number of carriers	4K	2K (106-MHz profile)
Multiplexing scheme	FDD	TDD, synchronized among different copper pairs
Vectoring	G.993.5	G.9701 (mandatory)
Tx power	14.5 dBm (varies by profile)	4 dBm / 8 dBm
Downstream/Upstream ratio	Fixed	Configurable (90:10–30:70)
Retrain time	Very long (30–90 s)	Very short (a few seconds)
Rate adaptation	Very slow (128 carriers at a time)	Very fast (quick and robust adaptation -- within a few ms)
Low power mechanisms	Under development	• Specified discontinuous operation

multiple neighboring VDSL lines when the system is deployed in apartment buildings. To counteract this FEXT interference, ITU-T standardized vectoring functionality. The vectoring works as follows:

1) FEXT interference levels among multiple lines are estimated within a single vectoring group.
2) The degree to which the interference level would be cancelled is calculated based on information on interference levels between relevant lines with respect to FEXT.
3) VDSL transmission power is controlled based on the above calculation.

It is possible to mitigate FEXT interference with this vectoring function and to provide much faster transmission services. It should be noted that vectoring functionality is a key feature of G.fast. Since G.fast is a transmission mechanism used for cable lengths of only a few hundred meters, it would seem logical that G.fast lines experience much more severe FEXT interference than VDSL lines. Therefore, although vectoring is specified as optional in the VDSL Recommendations, Recommendation G.9701 for G.fast specifies this vectoring functionality as mandatory. Although there are some VDSL systems that utilize vectoring with several hundred lines as a vectoring group, the current vectoring function for G.fast systems only works with 16 to 24 lines as a vectoring group. This would indicate that intensive calculations to estimate FEXT interference levels among multiple lines are necessary for vectoring. However, in view of the fact that the vectoring functionality is one of the most essential features of G.fast systems, it is expected that further development of vectoring functionality implementation will accelerate the number of lines that G.fast can handle.

Table 2 lists detailed functionalities and features other than vectoring that are implemented in both VDSL and G.fast systems. Although both technologies use some common mechanisms such as OFDM modulation and FEC (forward error correction), G.fast specifications include much more sophisticated improvements in order to realize an ultrahigh transmission scheme. Some of the details are as follows:

- Extension of frequency bands that would result in a 106-MHz profile and a 212-MHz profile, in order to realize transmission rates of 1 Gbit/s
- Use of TDD mechanism making it possible to change the ratio of upstream and downstream transmission rates
- Realization of low power consumption by both low transmission power mechanisms and the introduction of a new low power mode

G.fast has been standardized with the following ITU-T Recommendations:

- G.9700, approved in April 2014, which specifies items relevant to regulations such as frequency and PSD
- G.9701, approved in December 2014, which specifies physical layer related items
- G.994.1 Amendment 4, approved in December 2014, which specifies code points of G.fast for the initial handshake procedure
- G.997.2, approved in May 2015, which specifies physical layer OAM (operations, administration, and management) functionality
- G.998.2 Amendment 4, approved in August

2015, which specifies Ethernet-based multi-pair bonding for G.fast

3. Next steps for G.fast

Currently, carriers in Europe and North America are examining the performance and capabilities that G.fast technology has shown in their labs and/or field trials, and are considering how this technology could be applied to their access network infrastructures. There seem to be various ways the technology could be deployed in access networks. BT in the UK is considering deploying G.fast distribution point unit (DPU) systems inside cabinets, where the distance from the DPU to the CPE is about 500 m, and also on telephone poles. Swisscom in Switzerland is thinking of deploying DPU systems in manholes where the distance to the CPE is about 150 m, while in Canada, Bell Canada is evaluating whether to deploy DPU systems in the basements of apartment buildings. Almost all of the major carriers in Europe and North America are expected to make the necessary preparations for commercial deployment of G.fast systems based on the results of their tests in labs and/or field trials.

Now that the basic standardization work in ITU-T has been completed, work is moving towards the next phase, taking into account the above-mentioned plans. Specifically, proposals have been made and discussions held on improving the functionality and performance such as raising the transmission signal power, which would result in longer transmission distances, and adding additional frequency bands. Furthermore, G.fast implementation over coaxial cables has recently been proposed. Indeed, it is not only the standardization activities in this field that need to be followed carefully. What the pioneering carriers and vendors are doing is equally important.

Yoshihiro Kondo
Senior Manager, Standardization Promotion & Technology Research Section, Network Technology Center, NTT Advance Technology Corporation.
He received an M.S. and Ph.D. in electrical engineering from Northwestern University in Evanston, Illinois, USA, in 1990 and 1994, with a specialization in signal processing. He worked for OKI Electric Industry Co., Ltd., where he developed optical access network systems. He joined NTT Advanced Technology in 2006. Since then, he has been working on standardization of access networking systems, home networking systems, and other areas. He is a member of the Institute of Electronics, Information and Communication Engineers and the Institute of Electrical and Electronics Engineers.

NTT Communications Corp.—Acquisition of Virtela and Provision of Arcstar Global Network Services

Takashi Ooi
Director, Member of the Board, and Head of Network Services Division, NTT Communications

Abstract

In May 2014, the Network Services Division of NTT Communications and Virtela Technology Services Incorporated jointly became the first provider to announce the global deployment of NFV (network functions virtualization)-enabled cloud-based network services. This article highlights how the new technology can address enterprise pain points and how it has benefited NTT Communication's customers since the launch.

Keywords: NFV, SDN, cloud

1. Introduction

In January 2014, NTT Communications (NTT Com) finalized the acquisition of Virtela Technology Services Incorporated (Virtela), one of the leading innovators in global cloud-based networking (**Photo 1**). This helped expand the service coverage of Arcstar Universal One—NTT Com's enterprise network service—to 196 countries/regions worldwide. Moreover, Virtela has brought in expertise that will accelerate NTT Com's network functions virtualization (NFV) and software-defined networking (SDN) development. The acquisition has delivered a clear message that we will lead the way to transform the traditional carrier business into a cloud-like service model.

Vendors and service providers have long been evaluating SDN and NFV with the aim of building a more flexible, agile network infrastructure that addresses enterprise needs. However, the evaluations have been limited to laboratories and field trials, with very few commercial deployments. Just a few months

Photo 1. From left: Ron Haigh, President and board member at Virtela; Vab Goel, Founder and Chairman of the Board of Directors at Virtela; and Takashi Ooi, Director, board member, and Head of Network Services Division at NTT Communications.

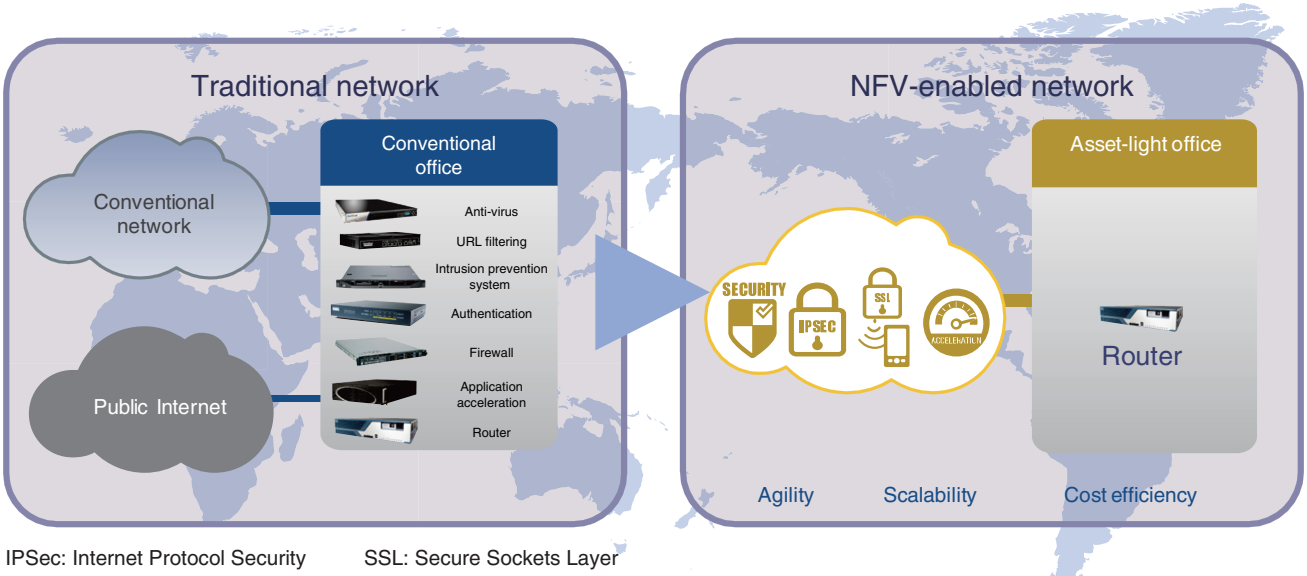


Fig. 1. NFV-enabled network.

after the completion of acquisition, NTT Com and Virtela announced the global launch of an NFV-enabled cloud-based network service. NTT Com has thus become the first global carrier to commercially deploy NFV-based service for enterprise users.

2. Enterprise wide area network (WAN) pain points today

The typical enterprise network now comprises hundreds or even thousands of network devices: firewalls, intrusion detection/prevention appliances, application accelerators, and more. They are typically proprietary hardware running a vendor-specific operating system. They are designed to be resilient and reliable, but they are also inflexible in the sense that it takes weeks and months to deliver them. Furthermore, enterprises must bear the capital cost of purchasing these devices, as well as the operational expenses of managing them. Recruiting skilled staff locally to operate the devices can also be challenging, depending on where the branch office is located.

Despite the competitive environment we are faced with today, traditional enterprise network services cannot scale quickly and flexibly to meet the changing business needs. Everyone is suffering: end-users are experiencing poor application performance and a lack of support for flexible work arrangements; network administrators are struggling to cope with configuration requests that can take days or weeks to handle while keeping track of multiple devices distributed worldwide; and security teams are fighting a war against 24/7 security threats. Information technology (IT) directors frequently have to overprovision, for instance, by investing in a heavy-duty firewall to provide temporary connectivity for a fixed-term project office.

Two new approaches to network architecture could help to transform networks into something more cloud-like. It offers agility, greater flexibility, and reduced complexity to help enterprises keep up with business.

3. Network functions removed from customer premises with NFV

NFV is an initiative by the European standards body, ETSI (European Telecommunications Standards Institute) to provide a technology akin to server virtualization. It removes the operating systems of proprietary hardware such as firewalls or application accelerators, and moves the functions to an array of standardized servers within our point of presence (POP). Each of these servers can also be virtualized so that we can add more processing power and virtual ports at will, and the software controlling the data flows is always up-to-date and configurable via a simple interface.

This means that our customers will no longer need to purchase and manage thousands of network devices themselves (**Fig. 1**). Network functionality can be

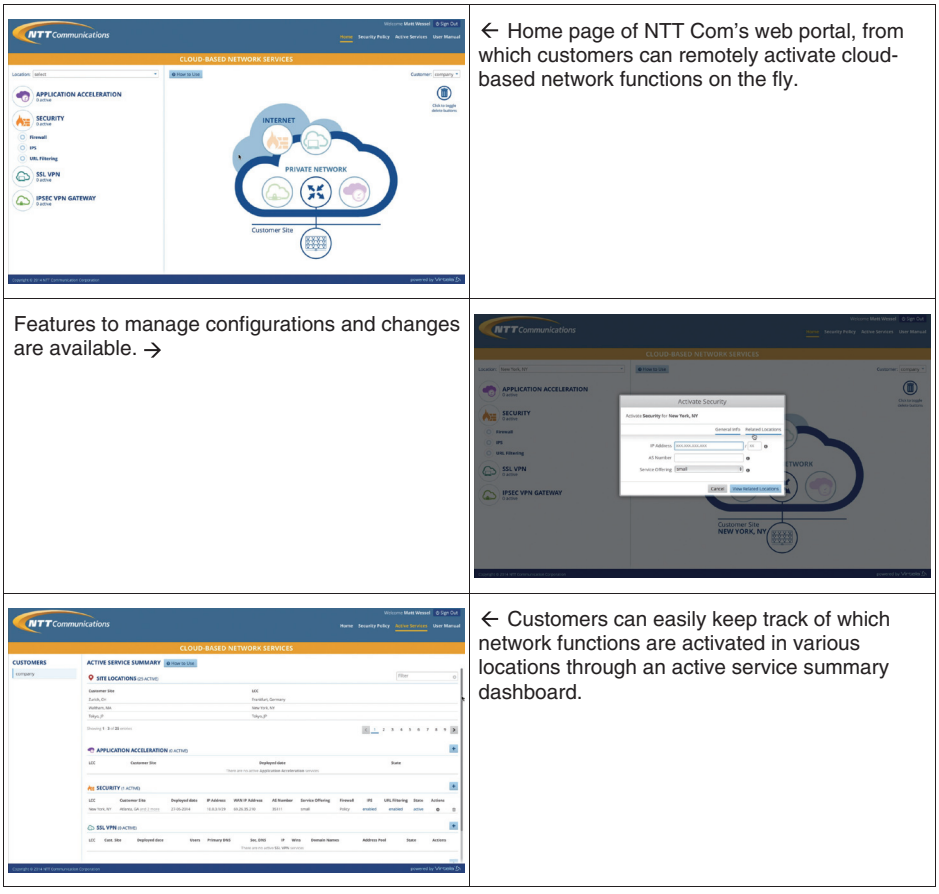


Fig. 2. NTT Com's SDN-enabled web portal.

delivered as a service from our private network. The only onsite equipment needed is a router, and this in future may also move to the carrier's POP.

4. Friendly support from SDN-enabled web portal

Another technology supporting the cloud-based network is SDN, which is frequently mentioned in the same breath as NFV. The two technologies are complementary; if NFV is an abstraction of the network services, SDN is an abstraction of the network architecture.

SDN breaks a network down to its constituent parts. The network control is decoupled from packet forwarding. In a traditional network device, the control layer needs to be constantly updated when there is a change in network paths so that it can direct packets onwards. With SDN, a centralized controller has a complete view of the entire network, and knowledge of all network paths and device capabilities sits in a single application. In other words, all of the network functions can be programmed remotely through a simple web portal. Our customers would only need to login to the portal and make a few clicks to provision the needed function per site. This reduces the service deployment lead time from weeks to minutes (**Fig. 2**).

5. Benefits of NFV and SDN today

Arcstar Universal One—NTT Com's secure private network service for enterprise users—now operates in 196 countries, with NFV and SDN at its core. NFV and SDN combined are transforming the network in the way cloud services is transforming the server infrastructure (**Fig. 3**).

The service enables our customers to become more agile and responsive to end-user needs with real-time activation and configuration changes through a web portal. New services can be provisioned in minutes as

Fig. 3. Arcstar Universal One—NTT Com's secure private network service for enterprise users.

opposed to weeks and/or months, meaning that enterprise pain points relating to onsite service deployment are removed.

The web portal also enables customers to scale resources up and down without having to purchase or manage additional devices. This means that IT resources are the right size for each situation, and customers save costs by only paying for what they consume during their required period. In fact, one customer has reported that they have reduced their original network spending by approximately 40%. Reducing the capital and operational expenses means that a portion of the enterprise IT budget can be allocated to strategic projects that support business growth.

NTT Com's cloud-based network services available today:

- **Cloud-based secure web gateway**—Offers firewall, intrusion prevention system (IPS), and URL (Uniform Resource Locator) filtering options, and enables secure Internet off-load for branch offices via the nearest NTT Com gateway. Enterprises can achieve better end-user experience while ensuring consistency in their web security policy across distributed branch offices.
- **Cloud-based application acceleration**—Optimizes application performance over the Arcstar Universal One Network, enabling global ICT (information and communication technology) consolidation and faster access to cloud-hosted applications by improving application response times and improving throughput.
- **Cloud-based SSL** (Secure Sockets Layer) **VPN** (virtual private network)—Enables remote workers or partners using any device with a browser to access the enterprise network resources securely, for improved productivity regardless of location.
- **Cloud-based IPSec** (Internet Protocol Security) **VPN gateway**—Establishes quick enterprise network connections from any site with Internet access. Connections can be customer-enabled so are ideal for enabling temporary connections and/or third party access.

6. Approaches to address enterprise network needs in the future

Enterprise network architectures have changed significantly over the past years, from hub-and-spoke topologies based on leased lines to fully meshed multiprotocol label switching (MPLS), and now to a hybrid WAN model that uses both MPLS and Internet.

Not so long ago, an enterprise would implement hybrid MPLS-Internet connectivity in an *active-standby* configuration as a back-up solution for fairly large sites. However, over the years, enterprise business needs for connectivity have evolved due to the emergence of public cloud services and the desire for

greater mobility. Network administrators can no longer fulfill enterprise business needs by sourcing a single MPLS connection between datacenters and branch offices but are required to design a hybrid network within the given budget. To address these challenges, NTT Com now delivers a hybrid WAN in an *active-active* model, with a path selection solution that enables our customers to identify the end-to-end path for specific applications.

We will also be launching Multi-Cloud Connect, which will improve the performance of cloud-hosted applications. The service provides direct connection to major cloud service providers, including Amazon Web Services*1, Microsoft Azure*2, and Office 365*2, from our MPLS network. All of these services are accessed via the Internet, meaning that end-to-end performance is often degraded due to traffic congestion and latency issues. Multi-Cloud Connect will improve application response time by enabling traffic to flow over secure, high performing MPLS and bypassing the Internet. In addition, Multi-Cloud Connect is also connected to Enterprise Cloud—NTT Com's private cloud service—to support the hybrid cloud environment.

Virtela operates today as a primary global vehicle, operating Arcstar Universal One services and providing the value-added features. Together, we will continue to strive to be the front runner in innovation and deliver pain point solutions for enterprises.

*1 Amazon Web Services is a trademark of Amazon.com, Inc. and its affiliates in the United States and other countries.

*2 Microsoft Azure and Office 365 are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

Takashi Ooi

Director, Member of the Board, and Head of Network Services Division, NTT Communications Corporation.

He received an MBA from Boston University, USA, and an M.S. in physics from the University of Tokyo, Japan. He has contributed to the success and innovation of NTT for nearly 30 years, having built his career entirely within the parent company and its subsidiaries. Over the course of three decades, he has gleaned direct insight and experience in the many facets and functions of the global organization's operations. He has led the network installations of multinational companies and contributed to the development of network services and international relations with business partners including regional/local carriers. In 2013, he oversaw the post-merger integration process of NTT Communications' complete acquisition of Virtela, a leading cloud-based network services company, which successfully resulted in an enhanced portfolio of services for enterprise customers.

Ron Haigh

President & Founding member, Virtela Technology Services Incorporated.

He received a B.E. in electrical engineering from the University of Missouri-Rolla, USA, and an M.E. in electrical engineering from the University of Texas at Austin, USA. He has an extensive background in developing breakthrough technology solutions in the fields of cloud computing and high performance networking. Prior to becoming a founding team member at Virtela, he was a senior member of the technical staff at Qwest and a group leader at Lawrence Livermore National Labs (LLNL). While at Qwest, he drove the industry's first all-optical network strategy and solution. During his years at LLNL, he led projects for multiple DoE (Department of Energy), DoD (Department of Defense), and DARPA (Defense Advanced Research Projects Agency) programs in the United States, and received DOE's Award of Excellence. He holds five patents.

Vab Goel

Founder, Chairman of the Board, Virtela Technology Services Incorporated.

He received a B.S. in electrical engineering from George Mason University, Virginia, USA. Prior to founding Virtela in 2000, he served as Vice President of Internet protocol (IP) Network Engineering and Advanced Technology at Qwest, where he created and implemented the Qwest IP Network and Data Center Strategy designed to enable seamless services with open standards and a strong customer focus. He also served Qwest as Vice President of Emerging Technologies, a group he also founded. In that position, he was responsible for identifying new networking technologies. He also fostered strategic relationships with start-up companies. Vab also worked at Sprint, where he was a principal architect for the Sprint Internet backbone and contributed to the company's IP and optical network strategy. He is also a venture capitalist at Norwest Venture Partners (NVP), where he focuses on mobile, security, cloud, networking, services, and Internet investments. He serves on the board of World View Enterprises and Virtela. He also works closely with Apigee, Pontis, and Mist Systems.

Improvements in Cable Surge Protectors

Abstract

Serious damage in telecommunication facilities can occur due to lightning surges. Cable surge protectors are effective in reducing the damage to telecommunication facilities caused by penetration of lightning surges to metallic cables. This article introduces the improvements that have been made to new cable surge protectors developed by NTT EAST. This is the thirty-fifth article in a series on telecommunication technologies. This month's contribution is from the EMC Engineering Group, Technical Assistance and Support Center, Maintenance and Service Operations Department, Network Business Headquarters, NTT EAST.

Keywords: lightning damage, cable surge protector, surge current

1. Introduction

Cable surge protectors are typically used to reduce lightning damage to telecommunication facilities. Nevertheless, the work required to install these devices is time-consuming. Moreover, ensuring there is sufficient installation space within terminal closures is required because the number of cable surge protectors to be installed depends on the total number of core wires in the target cable. We have therefore developed a new, more compact cable surge protector that improves connection workability. The following sections introduce this new surge protector.

2. Lightning damage to telecommunication facilities

Tall antenna towers are built on telecommunication buildings, and consequently, these towers are often struck by lightning. Metallic cables are connected to the telecommunication buildings that accommodate subscribers or have telecommunication or broadcasting towers, and also to wind farms or other structures. These cables are vulnerable to the surges caused by direct lightning strikes flowing into the telecommunication facilities. An example of damage to telecommunication facilities caused by lightning surge current is shown in **Fig. 1**.

Surge current caused by direct lightning strikes on steel towers or windmills flows into metallic cables. This current often damages the telecommunication equipment installed in NTT buildings, the telecommunication devices in customer premises, and also the metallic cables themselves and their connection points. Lightning damage in metallic cables is caused by an insulation breakdown between core wires or between a core wire and the cable's aluminum sheath. In addition, indirect lightning surge current can occur in metallic telecommunication cables when lightning strikes nearby power lines or trees, or when intercloud discharges occur.

3. Overview of cable surge protector

A cable surge protector can bypass surge current to a ground electrode through multiple connections to the core wires of a metallic cable. The connection configuration of the cable surge protector is shown in **Fig. 2**.

3.1 Connection of cable surge protector

The cable surge protector is connected by splicing it to each of the core wires. For greater lightning protection, the protector is connected by hand soldering it to core wires, instead of using pair transferable splicing (PAT) or multiple connectors. Each cable

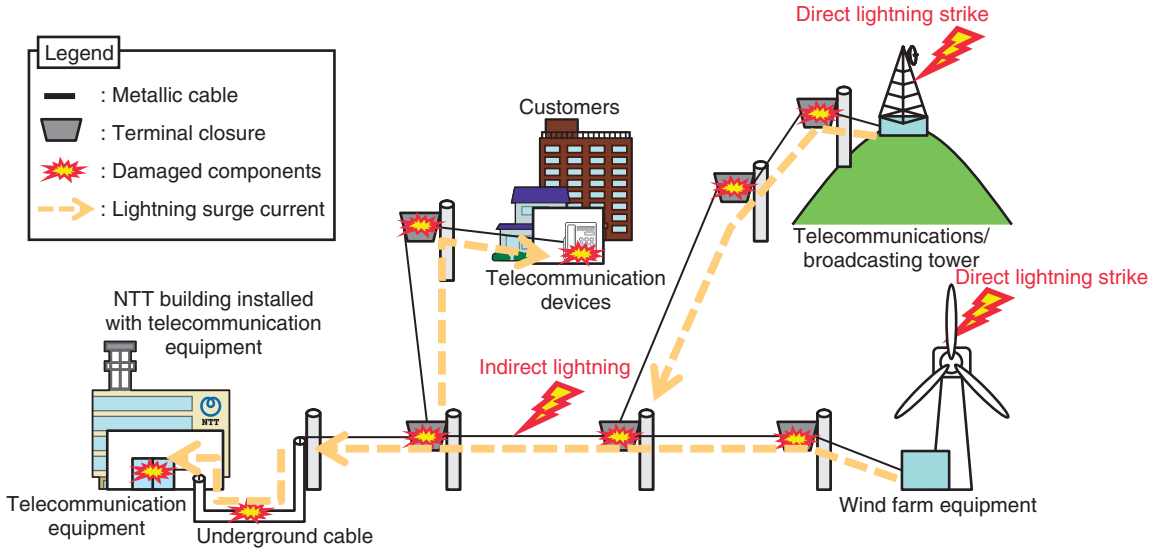


Fig. 1. Example of damage to telecommunication facilities caused by lightning surge current.

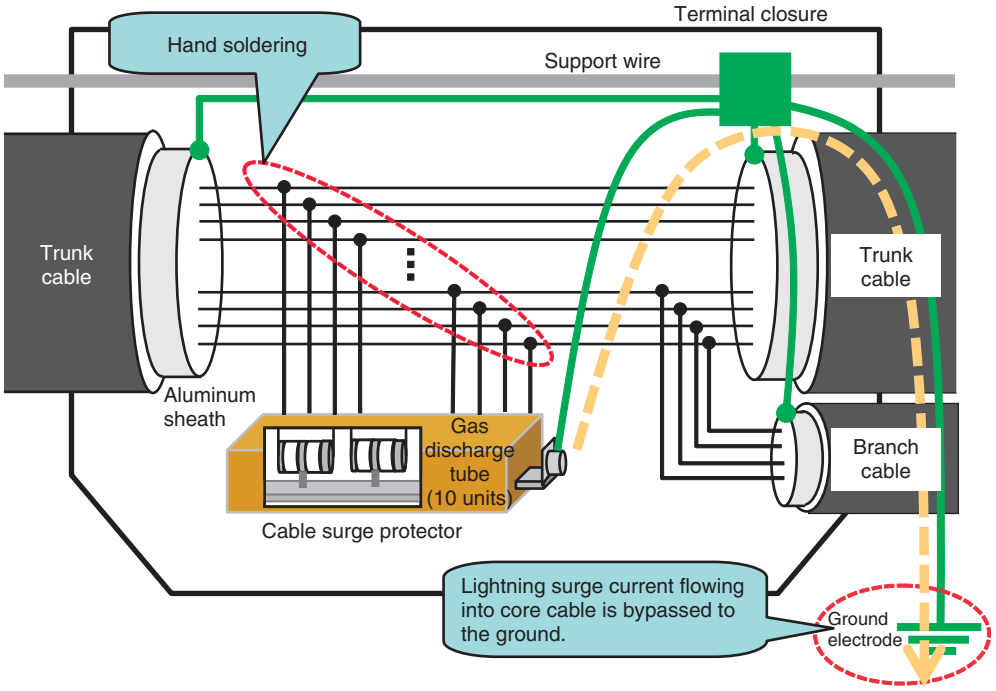


Fig. 2. Connection configuration of cable surge protector.

surge protector unit can be connected to ten pair wires. All core wires must be connected to a cable surge protector in order to prevent insulation breakdown between the core wires. This means that multiple surge protectors may be needed depending on the number of core wires. Recommended locations for installing cable surge protectors are the terminal closure at the cable pull-in pole on steel towers and wind turbines, which are metallic cable branching points, and the locations where core wires of different

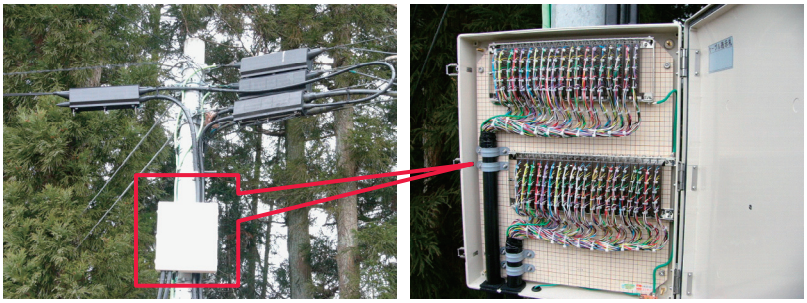


Fig. 3. Dedicated-box-type cable surge protector.

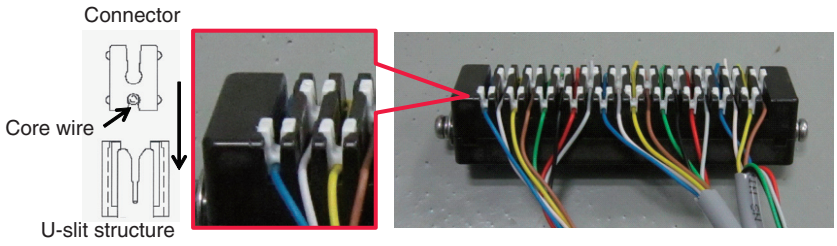


Fig. 4. New connection method for improved cable surge protector (prototype).

diameters are connected. Cable surge protectors should be installed in terminal closures placed at 500-meter intervals along a cable route.

3.2 Effects of using cable surge protector

Lightning surge current that flows into the core wires of the cable is released to a ground electrode via a gas discharge tube installed in the cable surge protector. This function protects the metallic cable and telecommunication facilities. It also prevents the insulation breakdown between the core wires themselves and between core wires and the aluminum sheath. When surge current due to a direct lightning strike with a large amount of energy exceeds the capability of the cable surge protector, the protector may break down. The cable surge protector can limit the area where the lightning damage occurs because it can bypass the surge current to a ground electrode.

4. Issues with existing cable surge protectors

PAT connectors are generally used to connect the core wires of metallic cable. However, such connectors may be damaged in the locations where surge current due to direct lightning strikes occurs. A cable surge protector must therefore be connected to each core wire by hand soldering, which is very time-consuming. Moreover, since all core wires must be connected, the number of cable surge protectors to be installed depends on the total number of core wires in the target cable. Therefore, it is necessary to ensure there is a sufficient installation space within a terminal closure. When the cable surge protectors cannot be installed in a terminal closure, it is possible to use cable surge protectors that are enclosed in a dedicated box for external use, which are installed on a utility pole. A dedicated-box-type cable surge protector is shown in **Fig. 3**.

In summary, cable surge protectors can be very effective to prevent lightning damage to metallic cables. The two key issues are that the connection task is very time-consuming and that sufficient installation space is needed.

5. Improvements to cable surge protector

5.1 Improving connection workability

A new connection method for a cable surge protector to simplify the connection task was investigated. The new connection method is shown in **Fig. 4**.

This method adopts U-slit structures for the improved cable surge protector. This connector can

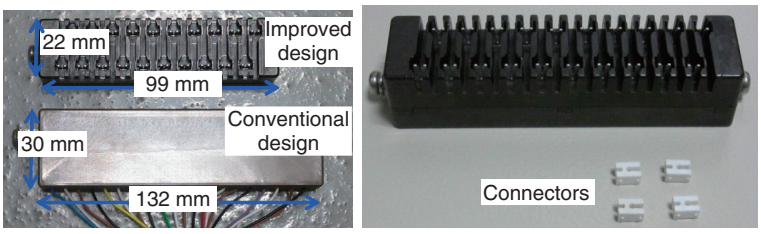


Fig. 5. External view of improved cable surge protector (prototype).

accommodate up to 20 core wires. The core wires were connected by crimp connection, which does not require dedicated connection tools. Core wires with diameters of 0.65 mm and 0.9 mm can be connected to the protector. (In terms of lightning protection, core wire diameters greater than 0.65 mm are preferable.) The crimp connection is made either at the top or bottom of the connector depending on the diameter of the core wire. In addition to improving connection workability, the use of crimp connection can also contribute to safer work operations because no soldering iron is needed.

5.2 Downsizing installation space

A means of downsizing the configuration of the cable surge protector to ensure sufficient installation space within the terminal closure was also investigated. An external view of the improved cable surge protector is shown in **Fig. 5**. To achieve a more compact cable surge protector, a new type of gas discharge tube (GDT), which is a major component of a surge protector, was developed. The conventional GDT design consisted of 2 signal electrodes and 1 ground electrode, making for a 3-electrode GDT for each core wire. In the new design, 10 signal electrodes and 1 ground electrode into an 11-electrode GDT for 5 core wire pairs were consolidated. This new GDT achieved performance equivalent to that of the conventional GDT, but with much less degradation, because it has a common internal arrester space (gap) instead of separated gaps. In this way, the main body of the cable surge protector can be made smaller because the new GDT size is smaller than the conventional one. Specifically, the dimensions of the cable surge protector were reduced from 132 × 30 × 15 mm to 99 × 22 × 19 mm, resulting in the volume approximately 30% smaller than that of the conventional product.

6. Functional verification

As described above, the improved cable surge protector adopts U-slit structures in the connecting section, a multi-electrode configuration, and a downsized enclosure. Therefore, there were concerns that this new structure might have less resistibility to lightning surge current than the conventional product. Accordingly, the resistibility to lightning surge current of the improved cable surge protector by using a prototype unit and the conventional one were compared. Specifically, we tested the maximum resistibility to surge current using a direct lightning strike surge current generator between all telecommunication line ports and the ground port, between each telecommunication line port and the ground port, and between telecommunication line ports themselves.

The results of these tests showed that no sparks or other problems occurred at the U-slit connection sections, contact points, or unused points, as a result of enclosure downsizing, and that the maximum resistibility to surge current was nearly equivalent to that of the conventional cable surge protector. These results indicate that an effective new cable surge protector that improves connection workability and downsizes the unit enclosure was achieved. The resistibility to lightning surge current of the new cable surge protector is the same as that of the conventional cable surge protector.

7. Conclusion

This article introduced a new downsized cable surge protector that improves workability. The plan going forward is to carry out trials in the field and to commercialize a surge protector product reflecting the results of these trials. The EMC Engineering Group of the Technical Assistance and Support Center is committed to the smooth provision of telecommunication services and to achieving prompt

solutions aimed to reduce the amount of lightning damage. To this end, we intend to actively focus on technology development, technology collaboration, and technology seminars.

External Awards

20th Award on Superconductivity Science and Technology
Winner: Hideki Yamamoto, Yoshiharu Krockenberger, NTT Basic Research Laboratories, and Michio Naito, Tokyo University of Agriculture and Technology
Date: March 3, 2016
Organization: The Society of Non-Traditional Technology Forum of Superconductivity Science and Technology

For discovery of undoped cuprate superconductors and research on their physical properties.

2015 Best Paper Award
Winner: Yuta Kikuchi, Tokyo Institute of Technology; Tsutomu Hirao, NTT Communication Science Laboatories; Hiroya Takamura, Manabu Okumura, Tokyo Institute of Technology; and Masaaki Nagata, NTT Communication Science Laboatories
Date: March 9, 2016
Organization: The Association for Natural Language Processing

For "Summarizing a Document by Trimming a Nested Tree Structure."
Published as: Y. Kikuchi, T. Hirao, H. Takamura, M. Okumura, and M. Nagata, "Summarizing a Document by Trimming a Nested Tree Structure," Journal of Natural Language Processing, Vol. 22, No. 3, pp. 197–217, Sept. 2015.

Telecom System Technology Award for Students
Winner: Daichi Kitamura, Graduate University for Advanced Studies (SOKENDAI); Hiroshi Saruwatari, The University of Tokyo; Hirokazu Kameoka, NTT Communication Science Laboatories; Yu Takahashi, Kazunobu Kondo, Yamaha Corporation; and Satoshi Nakamura, Nara Institute of Science and Technology
Date: March 28, 2016
Organization: The Telecommunications Advancement Foundation

For "Multichannel Signal Separation Combining Directional Clustering and Nonnegative Matrix Factorization with Spectrogram Restoration."
Published as: D. Kitamura, H. Saruwatari, H. Kameoka, Y. Takahashi, K. Kondo, and S. Nakamura, "Multichannel Signal Separation Combining Directional Clustering and Nonnegative Matrix Factorization with Spectrogram Restoration," IEEE/ACM Transactions on Audio, Speech, and Language Processing, Vol. 23, No. 4, pp. 654–669, Apr. 2015.

SIP Technical Meeting Award 2016
Winner: Fumihiko Ishiyama, NTT Network Technology Laboratories
Date: March 2016
Organization: The Institute of Electronics, Information and Communication Engineers (IEICE) Engineering Sciences Society, Technical Committee on Signal Processing (SIP)

For "Method of Disaggregating Appliances from an Aggregate Current Waveform on a Power Distribution Board."
Published as: F. Ishiyama, H. Inoue, and Y. Suzuki, "Method of Disaggregating Appliances from an Aggregate Current Waveform on a Power Distribution Board," IEICE Tech. Rep., Vol. 115, No. 522, SIP2015-183, pp. 379–384, Mar. 2016.

Chairman's Prize
Winner: Keisuke Nishi, Shigeo Otsu, Seiji Yoshida, and Takashi Hirose, NTT Network Technology Laboratories
Date: March 2016
Organization: IEICE Communications Society, Technical Committee on Communication Systems (CS)

For "Improvement of the Time Synchronization Precision by the Network-assisted GPS Time Synchronization Systems."
Published as: K. Nishi, S. Otsu, S. Yoshida, and T. Hirose, "Improvement of the Time Synchronization Precision by the Network-assisted GPS Time Synchronization Systems," IEICE Tech. Rep., Vol. 115, No. 406, CS2015-73, pp. 1–6, Jan. 2016.

The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, Prizes for Science and Technology (Development Category)
Winner: Masahito Tomizawa, NTT Network Innovation Laboratories; Hiroshi Onaka, Fujitsu Limited; Takashi Mizuochi, Mitsubishi Electric Corporation; and Kiyoshi Fukuchi, NEC Corporation
Date: April 20, 2016
Organization: Ministry of Education, Culture, Sports, Science and Technology

For the development of 100G digital coherent optical network technology.

The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, Prizes for Science and Technology (Research Category)
Winner: Makio Kashino, NTT Communication Science Laboratories
Date: April 20, 2016
Organization: Ministry of Education, Culture, Sports, Science and Technology

For the research on human auditory mechanisms that support human perception in various environments.

The Young Scientists' Prize of the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology
Winner: Haruki Sanada, NTT Basic Research Laboratories
Date: April 20, 2016
Organization: Ministry of Education, Culture, Sports, Science and Technology

For the research on electron spin manipulation in semiconductor quantum structures.

Best Research Award
Winner: Akihiro Shimoda, Keisuke Ishibashi, Shigeaki Harada, NTT Network Technology Laboratories; Kazumichi Sato, NTT Communications; Masayuki Tsujino, NTT Network Technology Laboratories; Takeru Inoue, NTT Network Innovation Laboratories; Masaki Shimura, Takanori Takebe, Kazuki Takahashi, Tatsuya Mori, Shigeki Goto, Waseda University
Date: June 1, 2016

Organization: IEICE Communications Society, Technical Committee on Internet Architecture (IA)

For "Inferring the Number of Accesses to Internet Services Using DNS Traffic."
Published as: A. Shimoda, K. Ishibashi, S. Harada, K. Sato, M. Tsujino, T. Inoue, M. Shimura, T. Takebe, K. Takahashi, T. Mori, and S. Goto, "Inferring the Number of Accesses to Internet Services Using DNS Traffic," Proc. of IA2015 (Workshop on Internet Architecture and Applications 2015), IA2015-63, pp.129–134, Nov. 2015.

KIYASU-Zen'iti Award

Winner: Hayato Fukuzono, Tomoki Murakami, NTT Access Network Service Systems Laboratories; Riichi Kudo, NTT DOCOMO; Yasushi Takatori, Masato Mizoguchi, NTT Access Network Service Systems Laboratories
Date: June 2, 2016
Organization: IEICE

For "Weighted-combining Calibration on Multiuser MIMO Systems with Implicit Feedback."
Published as: H. Fukuzono, T. Murakami, R. Kudo, Y. Takatori, and M. Mizoguchi, "Weighted-combining Calibration on Multiuser MIMO Systems with Implicit Feedback," IEICE Trans. Commun., Vol. E98-B, No. 4, pp. 701–713, Apr. 2015.

Best Paper Award

Winner: Hayato Fukuzono, Tomoki Murakami, NTT Access Network Service Systems Laboratories; Riichi Kudo, NTT DOCOMO; Yasushi Takatori, Masato Mizoguchi, NTT Access Network Service Systems Laboratories
Date: June 2, 2016
Organization: IEICE

For "Weighted-combining Calibration on Multiuser MIMO Systems with Implicit Feedback."
Published as: H. Fukuzono, T. Murakami, R. Kudo, Y. Takatori, and M. Mizoguchi, "Weighted-combining Calibration on Multiuser MIMO Systems with Implicit Feedback," IEICE Trans. Commun., Vol. E98-B, No. 4, pp. 701–713, Apr. 2015.

Papers Published in Technical Journals and Conference Proceedings

Feasibility of Traffic Matrix Estimation Scheme on Service-integrated Carrier Networks

Y. Uematsu, S. Kamamura, R. Sugiyama, T. Takeda, T. Miyamura, and K. Sasayama

IEICE Transactions on Communications (Japanese Edition), Vol. J98-B, No. 3, pp. 255–265, March 2015.

Each network provider promotes multi-service integration on a substrate IP network for cost reduction. For continuous optimization of facilities or network topology, it is necessary to accurately grasp the traffic structure of each service with its variations. This paper proposes a traffic structure analysis framework for service-integrated carrier networks, with an emphasis on improvement of the traffic matrix estimation scheme based on Tomo Gravity for estimation accuracy and extensibility for large-scale networks. Performance attributes of the prototype software indicate the feasibility of the proposed scheme on nationwide service-integrated carrier networks.

Machine-learning-based Prediction of a Missed Scheduled Clinical Appointment by Patients with Diabetes

H. Kurasawa, K. Hayashi, A. Fujino, K. Takasugi, T. Haga, K. Waki, T. Noguchi, and K. Ohe

Journal of Diabetes Science and Technology, Vol. 10, No. 3, pp. 730–736, October 2015.

About 10% of patients with diabetes discontinue treatment, resulting in the progression of diabetes-related complications. The objective was to predict a missed clinical appointment (MA), which can lead to discontinued treatment for diabetes patients. A machine-learning algorithm was used to build a logistic regression model for MA predictions. Data were extracted from electronic medical records and classified into two groups: one related to patients' clinical condition (X1) and the other related to previous findings (X2). The records used were those of the University of Tokyo Hospital, and they included the history of 16,026 clinical appointments scheduled by 879 patients. Records between April 1, 2011, and June 30, 2014, were inspected for a history of MAs. The best predictor of MAs proved to be X1 + X2 (AUC = 0.958). Our findings may provide information to help clinicians make timely interventions to avoid MAs.

View-directional Consistency Constraints for Robust 3D Object Recognition

J. Shimamura, T. Yoshida, Y. Taniguchi, H. Yabushita, K. Sudo, and K. Murasaki

IIEEJ Transactions on Image Electronics and Visual Computing, Vol. 3, No. 2, pp. 164–173, December 2015.

Robust object recognition is the key to real-world visual search applications. This paper proposes a novel geometric verification method to handle 3D viewpoint changes under cluttered scenes for robust object recognition.

GPS Trajectory Data Enrichment Based on a Latent Statistical Model

A. Kinoshita, A. Takasu, K. Aihara, J. Ishii, H. Kurasawa, H. Sato, M. Nakamura, and J. Adachi

Proc. of ICPRAM 2016 (the 5th International Conference on Pattern Recognition Applications and Methods), pp. 255–262, Rome, Italy, February 2016.

This paper proposes a latent statistical model for analyzing global positioning system (GPS) trajectory data. Because of the rapid spread of GPS-equipped devices, numerous GPS trajectories have become available, and they are useful for various location-aware systems. To better utilize GPS data, a number of sensor data mining techniques have been developed. This paper discusses the application of a latent statistical model to two closely related problems, namely, moving mode estimation and interpolation of the GPS observation. The proposed model estimates a latent mode of moving objects and represents moving patterns according to the mode by exploiting a large GPS trajectory dataset. We evaluate the effectiveness of the model through experiments using the GeoLife GPS Trajectories dataset and show that more than three-quarters of covered locations were correctly reproduced by interpolation at a fine granularity.

Shared-resource-pool Design Scheme for Failure-resilient Optical Transport Network

Y. Uematsu, M. Nakagawa, H. Yamamoto, S. Kamamura, K. Genda, and M. Katayama

IEICE Transactions on Communications (Japanese Edition), Vol. J99-B, No. 4, pp. 345–355, April 2016.

This paper introduces a shared-resource-pool control scheme and operation architecture utilizing flexible optical wiring infrastructure and centralized controlling technologies to achieve a higher availability and facilitated maintenance scheme in nationwide optical transport network across thousands of office buildings. It also proposes a design scheme of resource-pool quantity and maintenance immediacy to achieve end-to-end high availability in nationwide transport network and shows performance attributes of pooled transport resources in terms of enhanced-network-availability and relaxation in network-maintenance constraints.

Interruption-free Optical Access Line Transfer System Using Ring Buffer

K. Noto, M. Inoue, K. Katayama, N. Honda, and T. Manabe

IEICE Transactions on Communications (Japanese Edition), Vol. J99-B, No. 5, pp. 381–389, May 2016.

We have been studying an optical line switching system that uses electronic and optical delay lines to realize error-free optical access line switching. However, the use of an optical delay line increases the size of the optical line switching system. Here, we propose a newly designed delay line system that includes a ring buffer electronic delay line, which enables the system size to be reduced. We constructed and evaluated a prototype system.

MPEG-4 Audio Lossless Coding (ALS) Applied to Archiving System of Recorded Audio Project

N. Harada, Y. Kamamoto, and T. Moriya

IPSJ Journal, Vol. 57, No. 5, pp. 1355–1364, May 2016.

This paper proposes an information package to be applied for archiving system of recorded audio project. The devised information package format complies with the Open Archival Information System reference model and its implementation makes use of an optimized MPEG-4 Audio Lossless Coding codec library for audio data compression.

Auditory Multi-stability: Idiosyncratic Perceptual Switching Patterns, Executive Functions, and Personal Traits

D. Farkas, S. L. Denham, A. Bendixen, D. Tóth, H. M. Kondo, and I. Winkler

PLOS ONE, Vol. 11, No. 5, 015481, May 2016.

We explored correlates of the individual switching patterns with executive functions, personality traits, and creativity. The main dimensions on which individual switching patterns differed from each other were identified using multidimensional scaling. Individuals with high scores on the dimension explaining the largest portion of the inter-individual variance switched more often between the alternative perceptions than those with low scores. The ego-resiliency personality trait, which reflects a tendency for adaptive flexibility and experience seeking, was significantly positively related to this dimension. Taking these results together, we suggest that this dimension may reflect the individual's tendency for exploring the auditory environment. Thus individual patterns of perceptual switching in the auditory streaming paradigm are related to some personality traits and executive functions.