Technology Innovation:
IT

1 Technology for Financial Applications of PBI

Having developed a proprietary public biometrics infrastructure (PBI) that provides a reliable method of online personal identification and that works by retrieving private keys from biometric information, Hitachi is using the PBI to provide a secure and convenient authentication platform.

The increasing digitalization of financial services has seen a growing trend toward customers using their smart devices to initiate purchases online, a procedure that in the past would have been done in person or by post. As the initial registration step of PBI involves comparing a camera image against the person's identification documents, it provides a more rigorous form of online identity verification.

Furthermore, Internet banking in recent years has been adopting Fast Identity Online (FIDO*), which uses biometric authentication in place of traditional passwords. When used together, FIDO and PBI make it possible for users who have lost their smartphone to continue accessing services via their public template stored on a server.

In the future, Hitachi plans to deploy this technology through collaborative creation with customers.

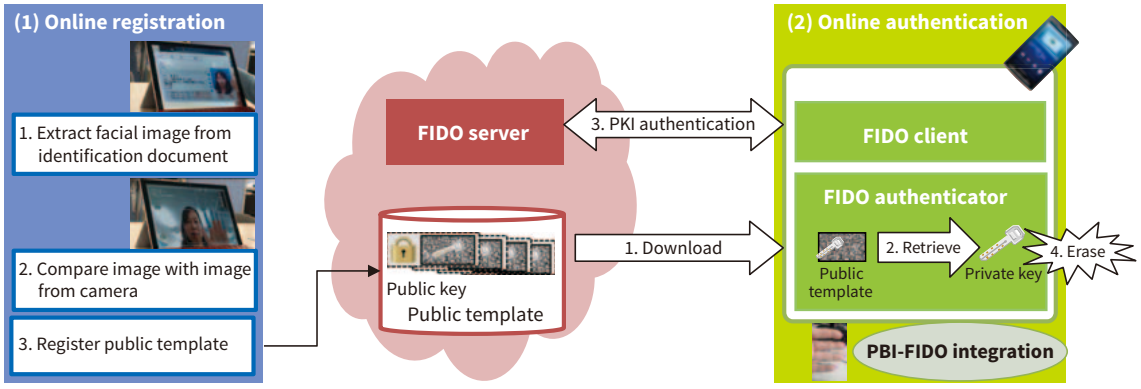
2 Development of Lift and Shift Technology for Migration to Public Clouds

The increasing migration to public clouds is happening as a means of cutting the cost and speeding up the process of system development. This includes both migration of existing systems to a public cloud ("lift") and upgrading to new cloud-ready systems ("shift").

Performing such a "lift and shift" requires the appropriate selection and interoperation of the services provided by the public cloud and that their use be secure. To improve security, appropriate privileges need to be set for the use of one service by another. Furthermore, determining whether the assigned privileges are adequate but no more than necessary is a trial and error process that takes up time. In response, Hitachi has developed an engine that determines the minimum set of privileges by assigning privileges for service interoperation and then testing whether these are needed, repeating this process until the "least privilege" settings are found.

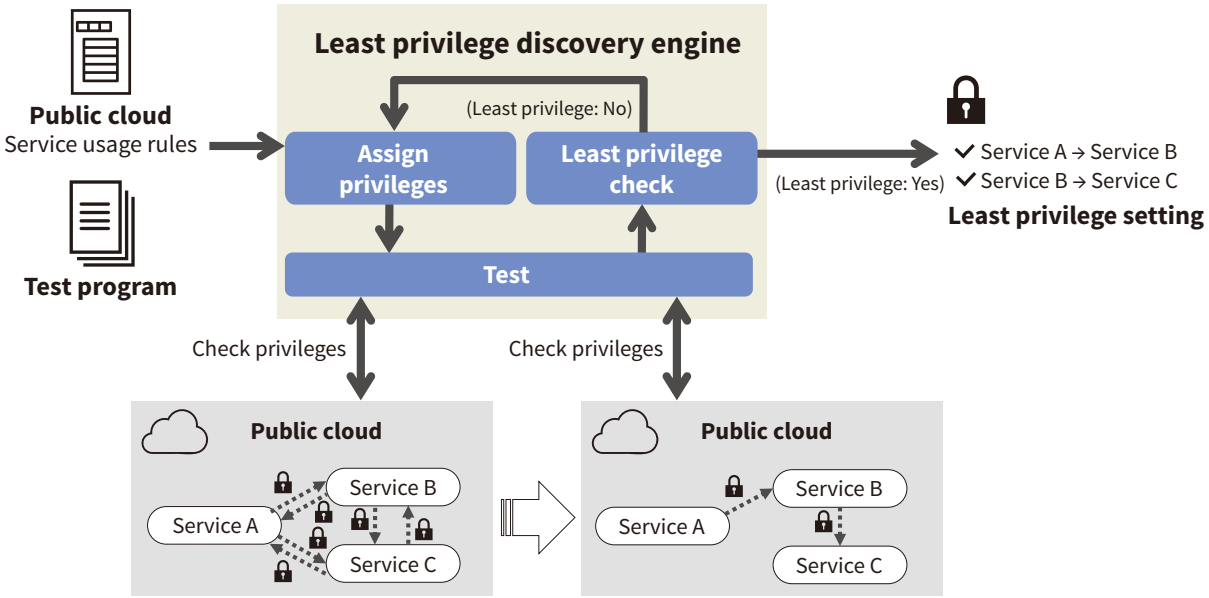
In the future, Hitachi intends to continue developing technology for the secure and efficient execution of lift and shift.

* See "Trademarks" on page 151.



PKI: public key infrastructure

1 Technology for financial applications of PBI



2 Overview of least privilege discovery engine for interoperation with public cloud services

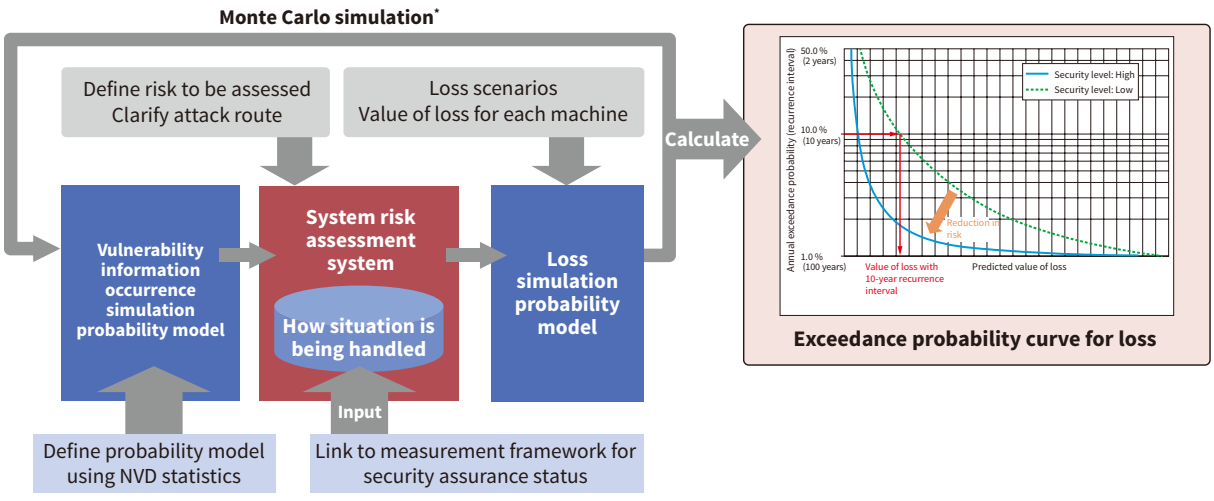
3 Quantification of Cybersecurity Risk

The threat of cyberattack has worsened in recent years, making cybersecurity measures increasingly important for a wide range of sectors as attack targets have extended beyond factories and industrial plants to include other important parts of the infrastructure of society, including energy, transportation, and finance.

Meanwhile, uncertainties about the risk of a security incident occurring and the return on security investment have made it difficult for business managers to judge how much they should be spending on such measures.

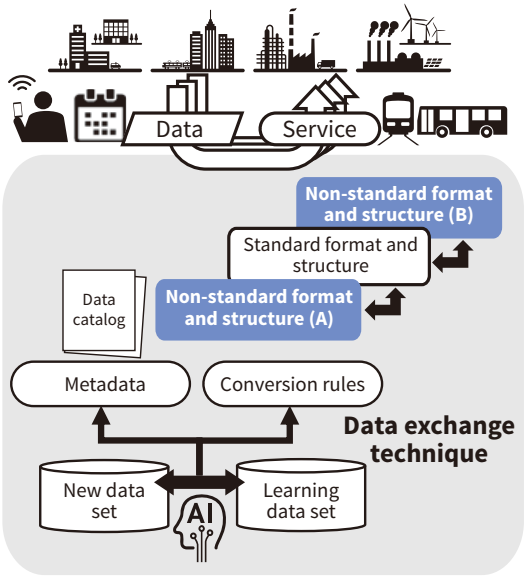
In response, joint research with Sompo Japan Nipponkoa Insurance Inc. and Sompo Risk Management Inc. has come up with a technique for the quantification of cybersecurity risk that is based on the catastrophe risk assessment model for natural disasters and also draws on a system risk assessment technique being developed by Hitachi that uses vulnerability information.

Specifically, the research and development are aimed at supporting investment decisions in industry and other important infrastructure sectors and involves a quantification technique using the annual value of losses due to security incidents and the probability of their occurring as represented by exceedance probability curves obtained from a loss model simulator.



NVD: National Vulnerability Database
* Numeric simulation technique based on use of random numbers

3 Calculation of exceedance probability curve using loss model simulator



AI: artificial intelligence

4 Data exchange technique for generating and supplying data catalogs and conversion functions

4 Data Exchange Technique for Accelerating Creation of Data-driven and Human-centric Services

Various countries are pursuing data-driven digital strategies such as Society 5.0, Thailand 4.0, and Digital India. While Japan possesses large amounts of high-quality data, it has not been put to good use because of the different data formats and structures used by different organizations or industries.

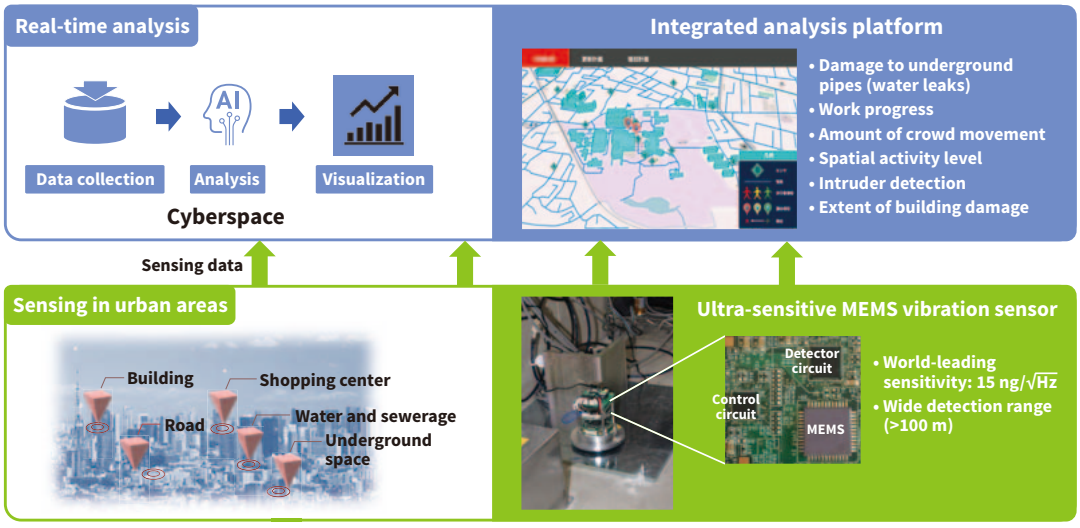
Hitachi has previously developed techniques for using accumulated learning data to extract metadata such as the location and type of new data from government statistics and other structured data to record this in catalogs or improve the efficiency of conversion to standard formats and structures. Current work involves extending this to non-structured data and data from the Internet of Things (IoT) and developing data distribution techniques for generating metadata and conversion rules.

In the future, Hitachi intends to work toward deploying the technique in practice to accelerate the creation of data-driven and human-centric services such as mobility services that utilize data on user movements, with plans for providing seamless transfers from trains to other modes of transportation like buses, taxis, and shared bicycles.

5 Digital City Monitoring

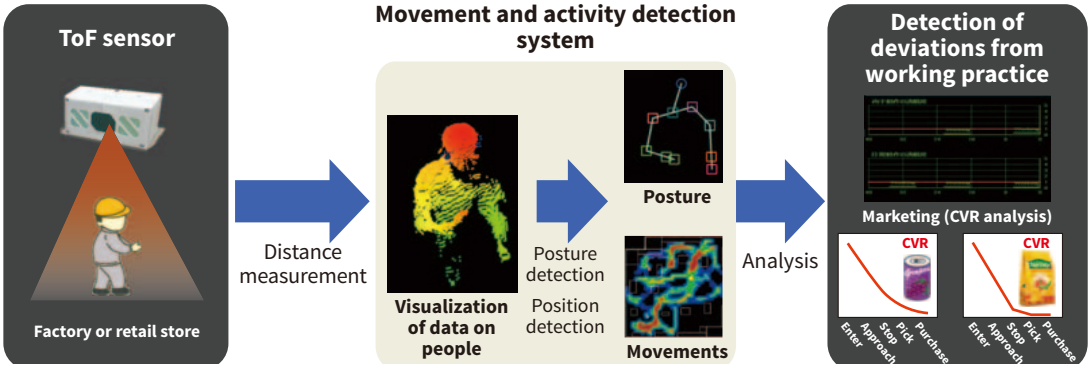
Hitachi is developing a digital city monitoring technique that uses ultra-sensitive vibration sensors with the aim of enhancing urban space values. Combining low power consumption with world-leading sensitivity of 15 ng/$\sqrt{\text{Hz}}$[*1], the Hitachi-developed sensor is able to collect information at a wide range (100 m or more) and for extended periods of time. These features can be utilized to monitor facilities such as buildings, roads, and shopping centers over large areas of a city.

Routine use of the technique can make maintenance more efficient by detecting damage to underground pipes, and enabling the efficient operation of urban spaces by monitoring things like work progress and the amount of crowd movement. In times of emergency,



MEMS: micro electromechanical systems

5 Digital city monitoring



CVR: conversion rate

6 Human activity and movement detection system using three-dimensional ToF sensors

the technique can help minimize damage and speed recovery by using the same sensors to determine the behavior of buildings and the extent of building damage[*2], for example.

In the future, Hitachi intends to help create a safe and secure society with a high quality of life (QoL) by expanding these contents further to provide greater visualization of urban activity.

*1 As of November 29, 2019, based on research by Hitachi, Ltd.
*2 Under development in partnership with Obayashi Corporation.

6 Human Activity and Movement Detection System Using Three-dimensional ToF Sensors

Three-dimensional time-of-flight (ToF) sensors measure three-dimensional data over a large surrounding area precisely with a precision not available from image analysis or motion sensors. Hitachi has developed a technique for measuring people's movements and other activities using only three-dimensional data (no image data).

The technique provides precise visualization of the activities of staff in offices or retail stores and, by developing models of staff working practices, can be used to analyze work efficiency, whether staff are doing things they shouldn't, and their state of tiredness or health. The results can also be provided back to the workplace as feedback to improve productivity or to make it more worker-friendly.

Applications of the technique include checkout-less retailing systems as well as a trial of its use in a system for the detection of deviations from working practice at a factory.

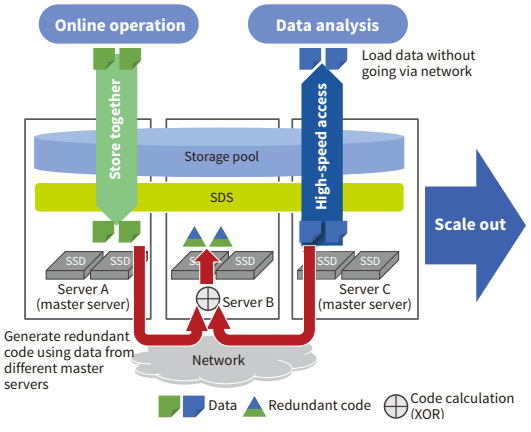
The problems for society posed by falling productivity due to a shrinking workforce can be resolved in the form of digital solutions for addressing this issue by technology for sensing the movement of people and providing the results of analyzing this information back to the workplace as feedback.

7 Accelerating Digital Transformation with Software-defined Storage

Software-defined storage (SDS) has attracted interest as a suitable means of storage for the digital transformation that is using data to transform business.

SDS involves a storage pool in which a number of general-purpose servers are consolidated by software to store data. A key feature is the ability to scale out capacity and performance simply by adding servers. This makes it a good fit with customer needs because it allows new data-based businesses to start small and then expand their IT infrastructure as the business grows.

SDS includes a function for storing multiple copies of data across different servers to prevent data loss in the event of server failure. Hitachi has developed a multi-server data protection technique that combines



SSD: solid state drive XOR: exclusive or

7 Multi-server data protection

efficient use of capacity with high performance. When an application writes data it is saved on the server that receives the data (the master server) and also forwarded for storage on another server. This other server combines data from different master servers to generate a redundant code and only stores this code so as to provide protection for the data in a way that makes efficient use of capacity. Because applications can read their data from the master server at high speed (without going via the network), this speeds up the analysis of large data sets that is essential for digital transformation.

8 CMOS Annealing

Hitachi has developed a complementary metal-oxide-semiconductor (CMOS) annealing technique for finding practical solutions quickly for large-scale optimization problems. Examples include scheduling optimization and portfolio optimization.

Following on from the past development of methods that use sparsely connected models implemented on devices such as application-specific integrated circuits (ASICs) or field-programmable gate arrays (FPGAs), an optimization algorithm for fully connected models has now been developed. The algorithm has been implemented on graphics processing units (GPUs) and tested using fully connected combinatorial optimization problems with 100,000 variables, demonstrating that approximate solutions could be obtained 250 times faster than the conventional simulated annealing method.

Hitachi intends to address a wide range of practical problems by making use of both this algorithm for fully connected problems and past CMOS annealing machines intended for sparsely connected problems, depending on the nature of the issues facing customers. Going forward, Hitachi will use the recently established *Kyoso-no-Mori* research and development facility to contribute to solving increasingly complex societal challenges through the collaborative creation of solutions with internal and external partners.

	CMOS annealing		Company A	Company B	Company C	Company D
Algorithm/ method	MA	SA	SB	SA/PTSA	CIM	QA
Hardware	GPU	ASIC/ FPGA	GPU	ASIC/ FPGA	Laser+ FPGA	SQUID
Spin coupling	Fully connected	Sparsely connected	Fully connected	Fully connected	Fully connected	Sparsely connected
No. of spins	100 k	100 k (→ 1 M)	100 k	8 k	2 k	2 k
No. of spins (fully connected graph conversion)	100 k	320 (→1 k)	100 k	8 k	2 k	61
Year announced	2019	2018	2019	2018	2016	2017

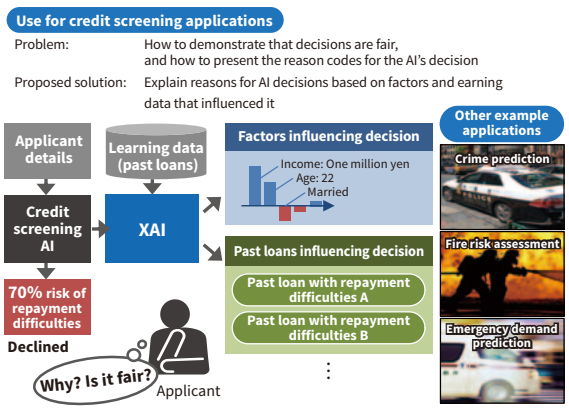
MA: momentum annealing SA: simulated annealing
SB: simulated bifurcation PTSA: parallel tempering simulated annealing
CIM: coherent ising machine QA: quantum annealing
SQUID: superconducting quantum interface device

8 CMOS annealing specifications

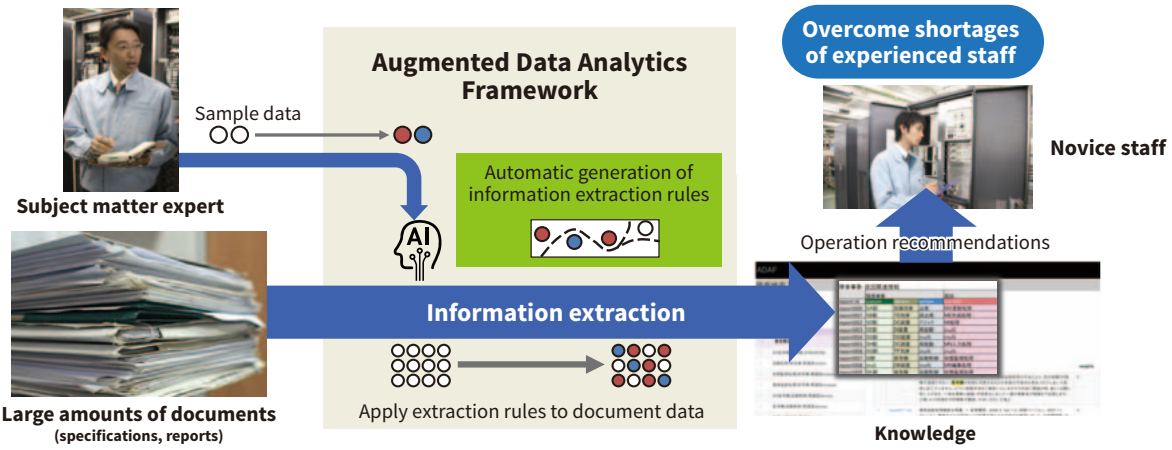
9 XAI: eXplainable AI

Advances in AI have led to rising public expectations for its use in mission-critical decision-making that directly affects life and property. On the other hand, the internal decision-making processes used by the advanced AI techniques of recent years such as deep learning are extremely complex, making it difficult for humans to understand why an AI has made a particular decision. This has led to concerns being raised about the use of AI in mission-critical applications that demand transparency and fairness in the reasons behind decisions.

To bridge the gap between these expectations and concerns, Hitachi has developed technology for eXplainable AI (XAI) that can retrofit a wide range of existing AIs with a function for explaining the reasons behind their decisions. To ensure that it can be used in practical AI applications to provide decisions that people will find convincing, XAI presents a combination of reasons behind decisions based on different perspectives. In doing so, Hitachi is helping facilitate the early adoption of AI that can be used with confidence in practical applications by providing a multi-faceted understanding of increasingly complex AI decisions.



9 Overview of XAI and example applications



10 Overview of Augmented Data Analytics Framework

10 Augmented Data Analytics Framework

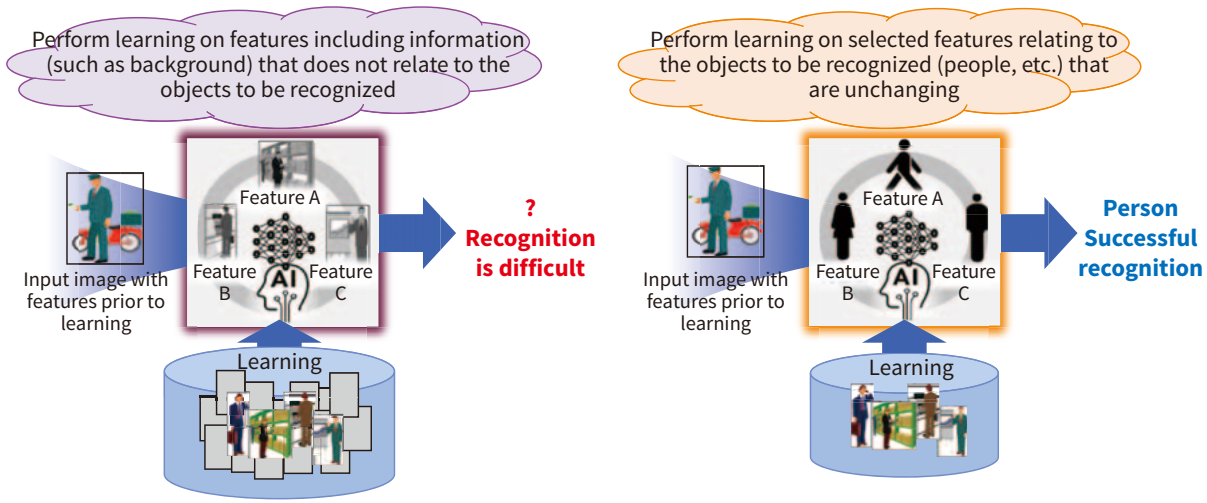
Recent years have seen rising interest in initiatives for using "dark data" to assist business in ways such as productivity improvement or cost reduction. Here, "dark data" means unstructured data that are utilized for a primary purpose once and stored inside companies, but are not utilized for any other secondary purposes.

Examples include the potential to provide optimal financial services based on an awareness of individual customer needs by extracting specialist financial knowledge from the many form documents used by financial institutions and combining it with advanced digital technologies. It is anticipated that this could accelerate work by financial institutions on new customer acquisition or sales promotion.

Putting this dark data to use in business, however, has required first that data of value to the business is extracted from this dark data and then that it be converted into suitable forms such as the table formats used by subsequent data processing, work that has proved very time-consuming in the past. In response, Hitachi has developed the Augmented Data Analytics Framework for extracting required information from large amounts of document type dark data. In fields such as manufacturing, for example, it is hoped that this will help overcome shortages of experienced staff by extracting the knowledge of such subject matter experts from product specifications and reports so that it can be reused.

11 Disentanglement Deep Learning for Precise Learning from Small Amounts of Data

Hitachi has developed a deep learning technique for image recognition AI that is capable of precise learning



11 Difference between old and new methods (for recognizing people in images)

from small amounts of data by disentangling the features for target objects into their elements during the learning process.

Past image recognition AI using deep learning needed a long time for data collection and learning because it the learning data needed to contain a mix of both target objects and background. The new technique disentangles the learning data into those features such as background that are not directly related to the target objects and the shapes and colors that indicate the essential image features of the targets. This disentangled data is then used for learning to produce an image recognition AI that can selectively recognize the latter type of features. Because this improves the accuracy of recognition of objects that include image features that have not been learned, it results in highly accurate image recognition AI even in cases where it has not been possible to collect large amounts of learning data.

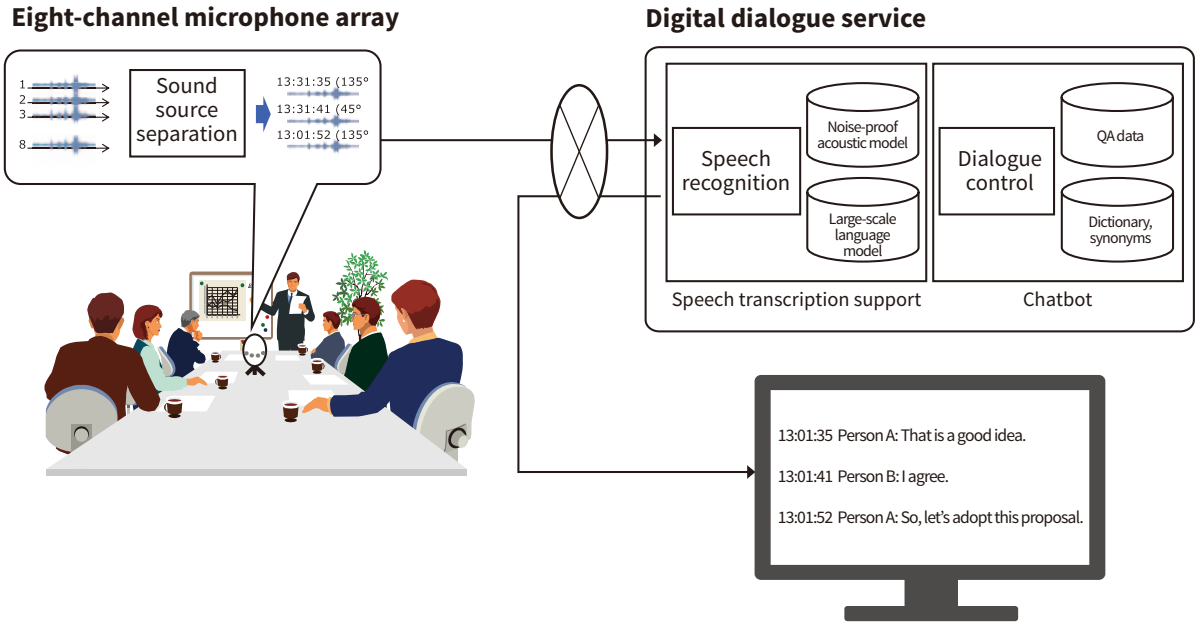
In the future, Hitachi intends to contribute to public safety and to improving the efficiency of manufacturing plants by making greater use of the technique in areas where collecting sufficient learning data would otherwise be difficult, such as the video surveillance of public places or use as an alternative to visual inspection in industrial applications.

12 Speech Recognition and Spoken Dialogue Technologies for Digital Dialogue Services

In response to societal challenges such as labor shortages and work-style reform, the technical requirements for the use of speech and text data at companies and for automating interactions with customers are becoming more stringent. Hitachi is addressing these needs by developing spoken dialogue technology, the initial target for which was use in communication robots.

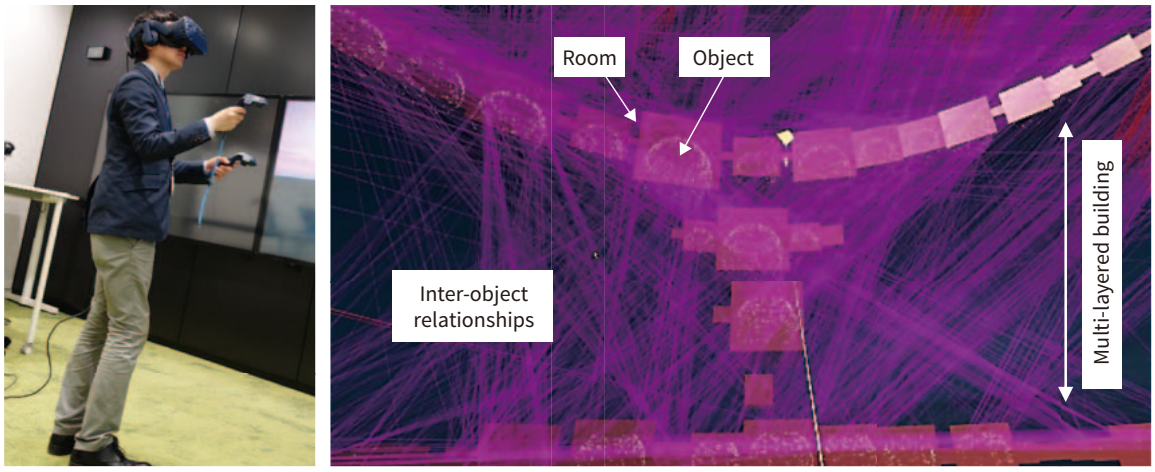
One outcome of this work was the commercial launch of the communication robot service in 2018. A transcription support function for meeting speeches and chatbot function (marketed as digital dialogue services) were also released in the same year. A feature of the transcription support function is that it uses an eight-channel microphone array installed at meeting venues to deliver highly accurate speech-to-text conversion that can pick up voices coming from multiple directions. To provide functions that would differentiate the product following its release, Hitachi has gone on to develop further technologies such as simultaneous speech recognition of multiple speakers and active learning technology which enables knowledge extraction from operational logs.

In the future, Hitachi intends to help corporate customers to achieve their digital transformation while



QA: question answering

12 Block diagram of transcription support service



13 Dependency graph arranged in VR space

also expanding its own digital dialogue service business by incorporating these powerful technologies into its products.

13 VR Source Code Visualization to Support Understanding of Software Structure

Hitachi has developed technology for software development more efficient by using virtual reality (VR) for the visualization of large and complex software structures. The technology uses the metaphor of a building to represent the structure of the software in VR, helping to provide an intuitive understanding of source code and identify where problems exist.

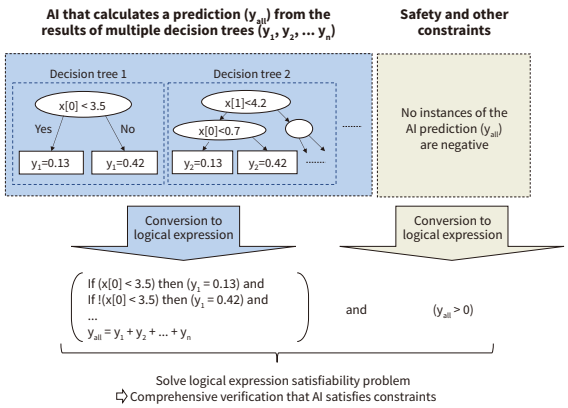
One of the issues when making modifies to large software is the difficulty of getting a clear view of the software structure given that there is a limit to how much information can be conveyed two-dimensionally on a display screen or similar. In response, Hitachi has developed tools that use the metaphor of a building to support the understanding of software structure at the macro level, that help the identification of software characteristics that are likely to result in bugs, and that help provide an understanding of the dynamic behavior of software.

In the future, Hitachi plans to use this technology to provide efficient software development environments.

14 Quality Assurance for Systems that Use AI

Quality assurance has become a concern over recent years for the increasing number of systems that incorporate AI. Particularly in the case of mission-critical systems that impact on the public, there is a need for ensuring, before a system is deployed, that AI behavior will not have negative consequences for human life or the economy. Unfortunately, when the number of possible inputs to an AI is large, testing all of these cases using conventional practices takes a very long time. In response, Hitachi has developed a comprehensive and automatic verification technique for AIs developed using deep learning and decision tree ensemble methods.

To verify that an AI satisfies safety and other constraints, the technique reduces this to the problem of deciding whether logical expressions generated from the AI and constraints are satisfiable. This provides an efficient way to perform comprehensive verification. When the technique was trialed on an AI comprised of 320 decision trees generated by decision tree ensemble learning, it succeeded in completing the comprehensive verification in only a few tens of hours. This technique will ensure safety and security in the rollout of systems that incorporate AI.



14 Comprehensive and automatic verification technique for AI