Research & Development

The graph shows the process of chronic disease onset and progression based on an analysis of actual data. Green indicates lifestyle, red indicates high blood pressure, blue indicates high blood sugar, orange indicates lipids, and black indicates complications.

1 Example of a model built using the new technology to predict chronic disease

1 Model for Predicting Incidence Rate of Chronic Diseases and Medical Costs Based on "Specific Health Checkups" and Prescription Data

To enable health insurance societies (health insurers) to establish highly cost-effective health maintenance businesses, Hitachi has developed a model for predicting the future incidence of chronic diseases and associated medical costs from the data that insurers hold on "specific health checkups" (checkups that focus on assessing the patient's risk of chronic disease) and medical claim data.

To model the processes through the onset and progression of disease, the new technology uses machine learning to automatically identify the patterns hidden in data to calculate the correlations between a large number of parameters, including test results, consultation records, diagnoses, examination and treatment details, and point allocations. Unlike conventional disease-specific models, this provides the model with a structure that is able to consider how different diseases interact, such as the interrelationships between diabetes, hypertension, and hyperlipidemia (abnormal lipid levels), for example.

When the validity of the new technology was assessed against data held by Hitachi Kenpo (Hitachi's health insurance arm) on approximately 110,000 people, it was found that total healthcare costs for chronic diseases could be predicted with a mean error of less than 5%. This enables health insurers to better control medical costs by using the model for things like identifying the health issues faced by people who are enrolled in their insurance schemes, or selecting health maintenance activities based on future medical costs.

2 MRI Measurement Technique for Early Detection of Neurodegenerative Brain Diseases

Hitachi has developed diffusion kurtosis imaging (DKI) and quantitative susceptibility mapping (QSM), two diagnostic applications that use magnetic resonance imaging (MRI) for the early detection of neurodegenerative brain diseases.

Many neurodegenerative diseases such as Parkinson's and Alzheimer's have similar physiological symptoms in their early stages, creating a need for diagnostic techniques that can distinguish them from each other. In the past, these diseases have been diagnosed from MRI scans in which the brain has undergone major morphological changes, meaning that a differential diagnosis could not be performed until the diseases had well progressed.

DKI uses the kurtosis (peakedness) of the transition probability distribution to determine the extent to which the diffusion of water molecules is restricted by tissue structure, allowing it to be used for imaging properties such as increases or decreases in the cell density or level of insoluble material in tissue. QSM, on the other hand, is a quantitative method for calculating the local variability of magnetic fields (magnetic susceptibility), and can be used for imaging things like changes in the concentration of iron in tissue. It is anticipated that the use of DKI and QSM analysis for the imaging of small changes in white matter and grey matter structures that occur in the early stage of disease will enable the development of techniques for the comprehensive early differentiation between various neurodegenerative diseases. To transform the new technology into a routine clinical test, Hitachi has developed a high-speed, high-precision image processing
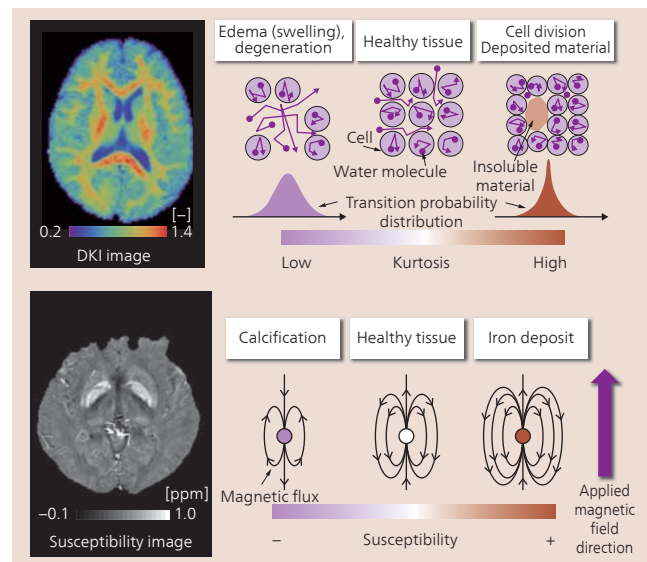
2 Overview of DKI (top) and QSM (bottom)
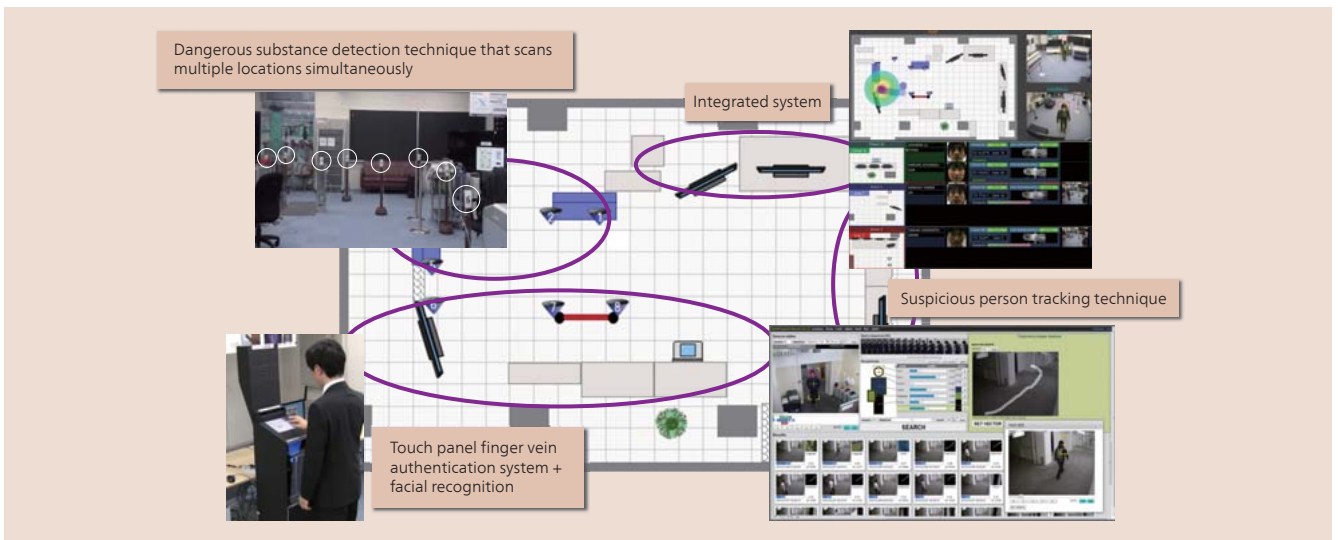
3 Prototype traceable physical security

algorithm that uses error propagation analysis to reduce the scanning time by identifying the scanning conditions that minimize computational errors, and that suppresses artifacts (false images) generated by the imaging calculation.

Joint clinical research currently in progress with Iwate Medical University is verifying the viability of the technique for early differential diagnosis.

3 Technology for Personal Identification, Dangerous Substance Detection, and Suspicious Person Tracking for Large-scale Critical Facilities

The prevalence of terrorist and criminal acts in the modern world places strong demands on the security systems that ensure public safety and security. The requirements for this include ways of verifying the safety of people and goods, and for rapidly extracting the relevant information from collected data.

Anticipating that these will be implemented at large public facilities, Hitachi has investigated the functions needed to combine the conflicting characteristics of high security and convenience in such applications. Ways of ensuring the safety of people have been consolidated under the concept of "traceable

physical security." In the prototype, Hitachi included a personal authentication technique that integrates facial recognition with a touch panel finger vein authentication system, a system for detecting explosives within an area using multi-point sampling, an integrated information viewer for the centralized management of the security situation within the area, and multi-perspective search for identifying suspicious persons in collected surveillance camera video.

4 Remote Work Support Technology Using AR and 3D Data Processing

Recent years have seen growing demand from organizations wanting to support overseas engineers and other workers from Japan, leading to interest in remote work support technology that provides a way to meet this need.

The remote work support technology developed by Hitachi uses augmented reality (AR) that provides workers with a heads-up information display to allow on-site workers and remotely located supervisors to share AR video and work progress information in realtime. It can provide a heads-up display of work instructions,

Research & Development
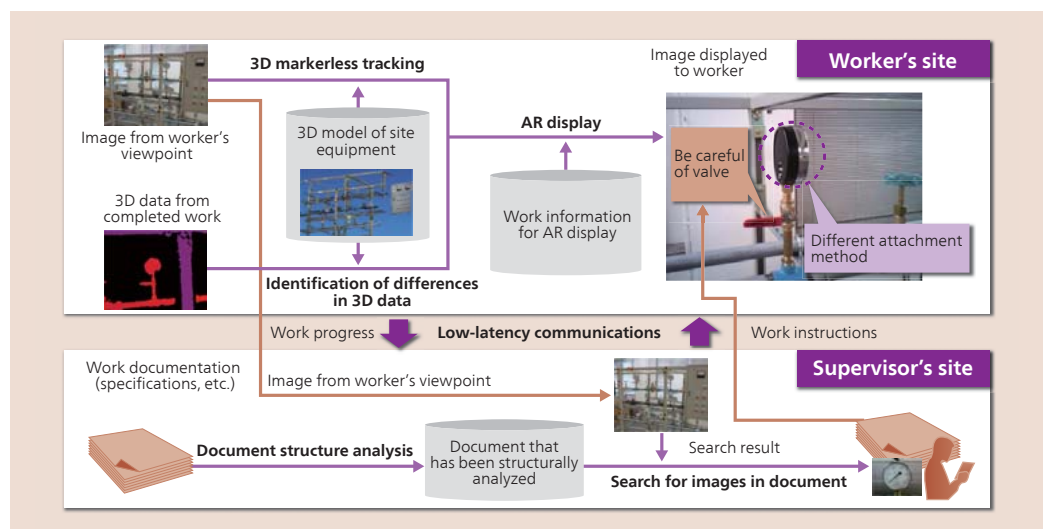
4 Remote work support system using AR and 3D data processing

information from manuals, and other material retrieved by the supervisor using images of equipment or parts in the AR video as search keys. It also helps the supervisor check the work by using a technique that compares three-dimensional (3D) data of what the completed work should look like with 3D data acquired at the site, thereby providing a realtime assessment of whether the work has been carried out appropriately.

In addition to enabling support of remote work to be conducted with precision, there are concerns about the decreasing number of experienced engineers, and the new technology is also recognized as having the potential to help pass on their skills and know-how.

5 Power-saving Technique for IT Systems that Adjusts LSI Drive Voltage Based on Permitted Error Rate
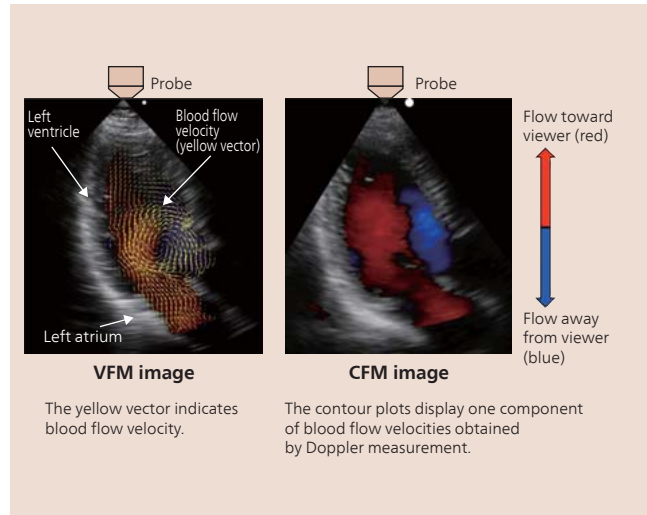
The miniaturization of large-scale integration devices (LSIs) that has underpinned improvements in the performance of information technology (IT) systems is now approaching the order of nanometers. This has led to problems with bit errors caused by the variation in internal transistor characteristics. While bit errors can be avoided by driving LSIs at a high voltage, this is an obstacle to reducing power consumption.

Given this background, Hitachi has devised a design criterion for IT systems that looks at the data error rate (permitted error rate) needed to maintain the application service value as well as the considerations of performance, power, and level of LSI integration that were taken into account in the past, using this as a parameter for optimizing the LSI drive voltage to improve energy efficiency. To achieve this, Hitachi developed a processing technique that makes more efficient use of power without causing system faults by maintaining the drive voltage at a level that ensures an error rate of zero during system control processing but reducing the drive voltage for other processing based on the permitted error rate.

This new technique can significantly reduce power consumption by IT systems despite the unavoidable physical device variation associated with future increases in the level of LSI miniaturization.
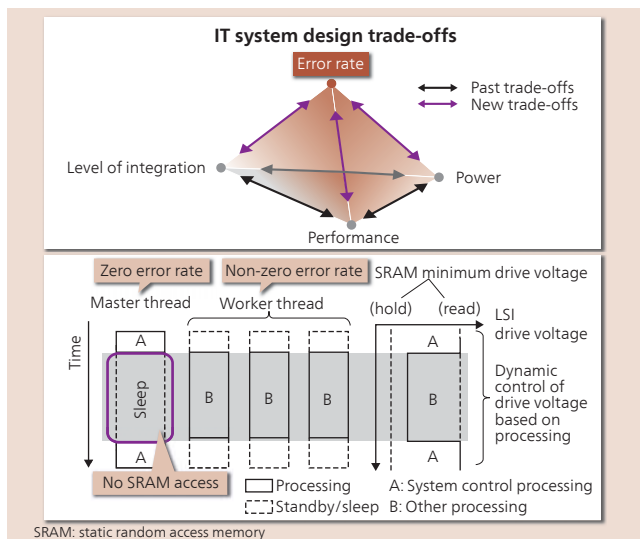
5 IT system design criterion (top) and processing technique for controlling LSI drive voltage based on the permitted error rate (bottom)

The yellow vector indicates blood flow velocity.

The contour plots display one component of blood flow velocities obtained by Doppler measurement.

6 Blood flow imaging showing the flow of blood from the left atrium to the left ventricle

6 VFM Technique for Cardiac Ultrasound

Hitachi has commercialized[*1] ultrasonic vector flow mapping (VFM), a non-invasive technique for imaging blood flow velocity vectors inside the heart that can be used for the early diagnosis of heart disease.

While the existing technique of color flow mapping (CFM) can only measure blood flow velocity in one direction, VFM overcomes this problem by combining the results of CFM measurement with a fluid mechanics model to calculate the blood flow vector.

In commercializing VFM, Hitachi needed to conduct experimental validation to confirm the accuracy of the calculated velocity vector, but no such method exists for accurately measuring blood velocity in the heart. Accordingly, Hitachi constructed an experimental system consisting of an optically transparent[*2] model heart with a beating motion that enabled a laser to be used to determine the vector field for internal blood flow, allowing a comparison of ultrasound and laser measurements. This enabled the commercialization of VFM to make a significant step forward.
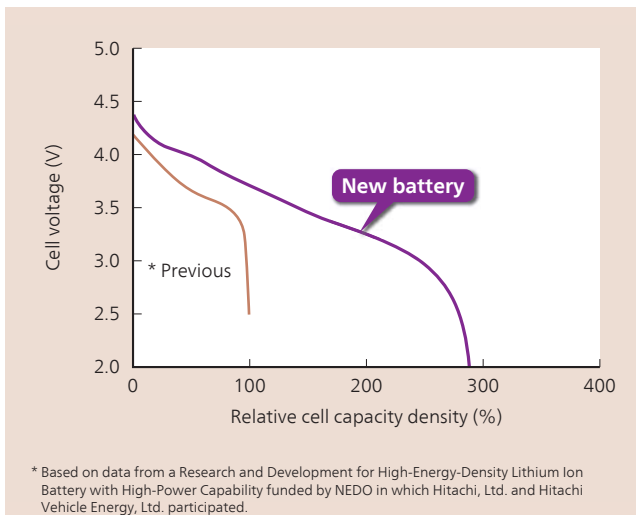
In the future, Hitachi intends to provide greater value to doctors and patients by further enhancing VFM based on feedback from clinical use.

*1 Product released by Hitachi Aloka Medical, Ltd. in July 2013.
*2 The simulated heart had the same refractive index as the simulated blood.

7 High-energy-density Lithium-ion Battery for Electric Vehicles

By developing technologies for achieving high energy density in lithium-ion batteries for electric vehicles, Hitachi has succeeded in improving cell capacity density by a factor of approximately 2.8. The technologies comprise high-capacity anode and cathode materials that improve the cell capacity density, and a thick electrode structure that increases the number of lithium-ions available for charging and discharging and increases the energy density.

* Based on data from a Research and Development for High-Energy-Density Lithium Ion Battery with High-Power Capability funded by NEDO in which Hitachi, Ltd. and Hitachi Vehicle Energy, Ltd. participated.

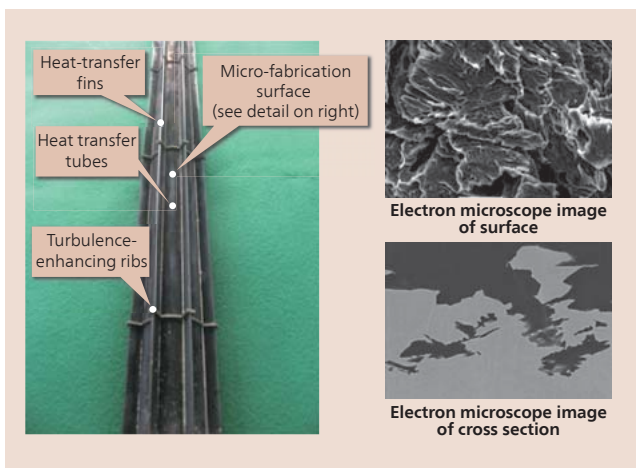**7** Discharge characteristics of newly developed lithium-ion battery with high energy density

An energy density of 335 Wh/kg and a power density of 1,600 W/kg were achieved for the 30 amp/hr-class cell applied in these technologies. This energy density is higher than previous performance by a factor of 2.6, and has the potential to significantly extend the driving range of electric vehicles.

In the future, Hitachi will continue with research and development aimed at developing lithium-ion batteries that incorporate these new technologies adopted for use in electric vehicles by conducting long-term reliability and other testing, and by seeking to resolve any outstanding problems.

Note that this research was conducted as part of the Applied and Practical Lithium Ion Battery Development for Automobile and Multiple Application Project of the New Energy and Industrial Technology Development Organization (NEDO).

8 Technology for the Inherent Safety of Nuclear Reactors

Hitachi has been developing inherently safe technologies for nuclear reactors to minimize the risk of radioactive material release into the environment even in a large scale natural disaster by enabling the long-term cooling of the reactor without elec-

tricity to drive pumps, fans, and other machineries. Specifically, Hitachi is researching systems that combine air cooling driven by the natural circulation of air with water cooling that does not involve the use of electric power to drive pumps and other machineries.

Since the heat removal ability of air is generally low, realizing an air cooling system in practice requires improvements to the cooling performance of air so that the air-cooled heat exchanger can be reduced to a reasonable size. Accordingly, Hitachi has developed technologies that roughly double the ability of air heat removal performance by forming tiny micrometer-sized undulations (micro-fabrication surface) in the heat transfer tubes of the heat exchanger, and also by forming millimeter-sized protrusions that act to stir the air flow (turbulence-enhancing ribs), and vertically oriented heat-transfer fins that do not obstruct the air flow.
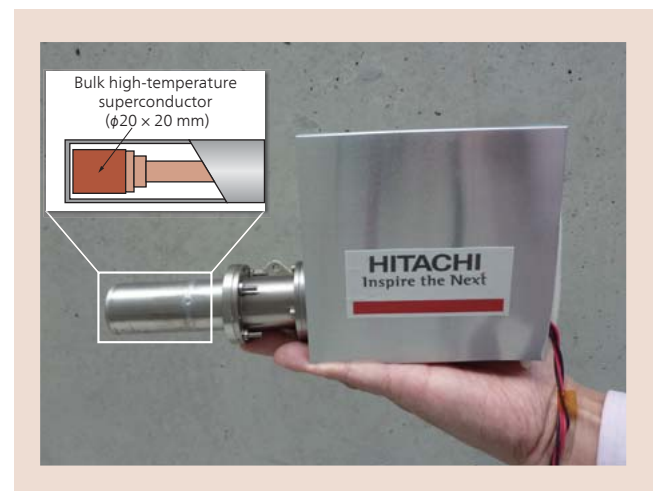
This technology roughly halves the number of heat transfer tubes required for reactor cooling and shrinks the air-cooled heat exchanger to a more reasonable size.

9 Miniature Superconducting Bulk Magnet

Hitachi has developed a palm-sized superconducting magnet with potential applications in magnetic drug delivery systems (MDDSs).

MDDSs use drugs that contain magnetic material. They work by applying a magnetic field to the affected site in the body so that the drug will concentrate in this region, thereby improving the drug's efficacy. Because this involves guiding the movement of nanometer-sized magnetic particles, it requires miniature superconducting magnets that can generate an intense magnetic field while still being easy to handle. Accordingly, bulk high-temperature superconductors (which become superconducting at higher temperatures than conventional superconductors) are used because they can work with small cooling systems that have a low cooling capacity. This has enabled the production of a miniature (palm-sized) superconducting bulk magnet that is able to produce a 3-T static field, similar to that of a medical MRI system.

In the future, Hitachi intends to investigate using the magnet for other applications in addition to MDDSs.

Electron microscope image of surface

Electron microscope image of cross section

8 Heat transfer tubes incorporating techniques for improving the ability of air to remove heat

Bulk high-temperature superconductor (φ20 × 20 mm)

9 Miniature superconducting bulk magnet

The robot uses the microphone array and camera in its head to recognize the speech and gestures of the person it is interacting with.

Anticipate and avoid person emerging from around corner.

10 How the humanoid robot avoids blindspots around corners (left) and an example of interactivity (right)

10 Human Symbiotic Robot

A humanoid robot (shown in the figure) has been developed to act as a guide in public places in Hitachi. To improve the ability of the robot to operate around people, Hitachi has used machine learning to upgrade its avoidance and interactivity technology.

With the upgraded avoidance technology, the robot learns the location and speed of pedestrians in the space through it is moving and is able, not only to avoid those pedestrians that are visible through its sensors, but also to anticipate and avoid people who could potentially emerge from around corners or other blindspots where its sensors cannot see. When the robot's path requires it to approach a blindspot, it decelerates for safety.

The upgrade to its interactivity technology, meanwhile, enables the robot to provide flexible responses to questions. Using a question interpretation model that has been adapted using deep learning, the technology can provide an appropriate answer to even unanticipated questions by identifying its subject and attributes. It can also estimate how well the person it is speaking to has understood based on nodding or tilting of the head, and respond naturally.

In the future, Hitachi will keep working to develop technologies that enable practical services.

## 11 Amorphous Motor that Achieves IE5 International Efficiency Standard

Rising public concern in recent years about global warming and other environmental problems has led to interest in technologies that boost the efficiency of electrical equipment. As a result, there is growing demand from countries around the world for the use of highly efficient electric motors to save power in industrial equipment and other applications, with the USA requiring electric motors to meet the IE3 standard or better since 2010, and Japan introducing the same requirement from FY2015.

Hitachi has been working on the development of axial gap motors that use an amorphous alloy core to significantly improve motor efficiency. This work included the successful production in 2012 of a prototype 11-kW amorphous motor that achieved an

IE4*-compliant energy efficiency of approximately 93%. Now, Hitachi has developed an amorphous motor that achieves the maximum IE5* level of the international efficiency standard for industrial motors. The prototype 11-kW amorphous motor has demonstrated an efficiency of 96%, and despite its smaller size has further reduced losses by 30% compared to the previous IE4-class motor.

Note that some of the technologies used in the new motor were developed to satisfy demand for further power savings through a product development process funded by the "Rare Metal Substitute Materials Development Project" of the New Energy and Industrial Technology Development Organization (NEDO).

* Motor efficiency guidelines defined by the IEC 60034-30/31 standard of the International Electrotechnical Commission (IEC).
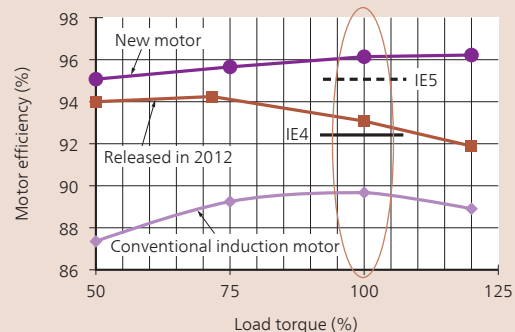
11 Prototype 11-kW motor that achieves the IE5 efficiency level (top) and comparison of efficiencies of 11-kW prototype motors (bottom)
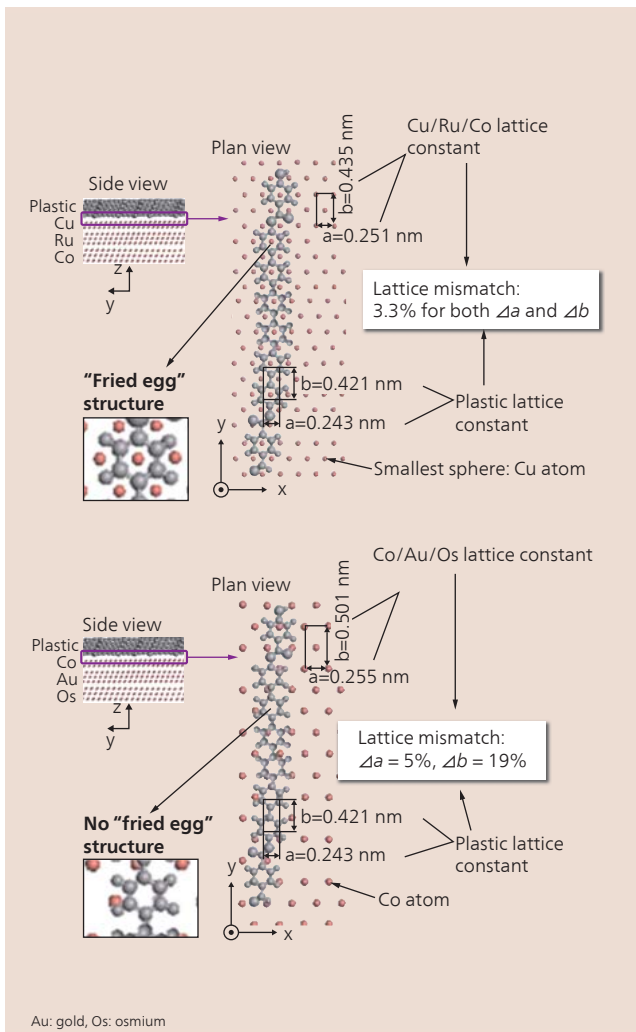
12 Results of atomic array calculation for high-adhesive-strength interface between plastic and Cu/Ru/Co (top) and low-adhesive-strength interface between plastic and Co/Au/Os (bottom)

12 Increased Adhesion of Plastic/Metal Interface Utilizing Orthogonal Arrays and Molecular Simulation

Because of their light weight, plastics are used in a wide range of products from electronic components to electrical equipment. In many cases, however, they suffer from poor adhesion to metals, ceramics, and other inorganic materials. In response, Hitachi has developed a technique that combines orthogonal arrays and molecular dynamics simulation for the efficient design of metals with excellent strength of adhesion to plastic.

Using the technique, a study of the most important factors in increasing the strength of adhesion found that the lattice mismatch between plastic and metal was crucial, and that the smaller the mismatch is, the stronger the adhesion will be. Lattice mismatch is a parameter that expresses the degree of inconsistency between atomic arrays, with the relative differences between the short edge (a) and long edge (b) of the unit cell being defined as Δa and Δb. When used to design a laminated metal film with excellent adhesion to the polyphenol resin used in semiconductors, a small lattice mismatch with the resin of only 3.3% was achieved by layering copper (Cu), ruthenium (Ru), and cobalt (Co), giving an adhesive strength 30% higher than that of a thin film made of Cu only. The mechanism by which the stronger adhesion is achieved

involves using a repeating "fried egg" structure consisting of Cu atoms inside a benzene ring to strengthen the inter-molecular bonds.

In the future, Hitachi intends to utilize the technology in the design of components such as enamel wire for motors or electrodes for lithium-ion batteries.

13 Wind Tunnel to Enhance Development of Rolling Stock for High-speed and European Trains

Hitachi has developed a wind tunnel for uses that include reducing aeroacoustic noise on high-speed rolling stock and improving the safety in crosswind of rolling stock for the European market.

The wind tunnel can predict the level of aeroacoustic noise by reproducing the air flow over moving rolling stock. The maximum air speed was increased from 180 kph previously to 420 kph by increasing the performance of the blower used to generate the flow of air and by optimizing the flow path shape from the blower to the air outlet. This can reproduce conditions similar to those of a high-speed train traveling at maximum speed and predict the level of aeroacoustic noise with good precision. The wind tunnel also includes a rolling stock safety test apparatus that complies with the safety testing requirements stipulated in the EN 14067-6 European standard to enable it to be used for the preliminary safety testing of rolling stock in crosswind required during development for the European market.

In the future, Hitachi intends to use this new facility for the development of rolling stock that is safer, more comfortable, and energy-efficient.
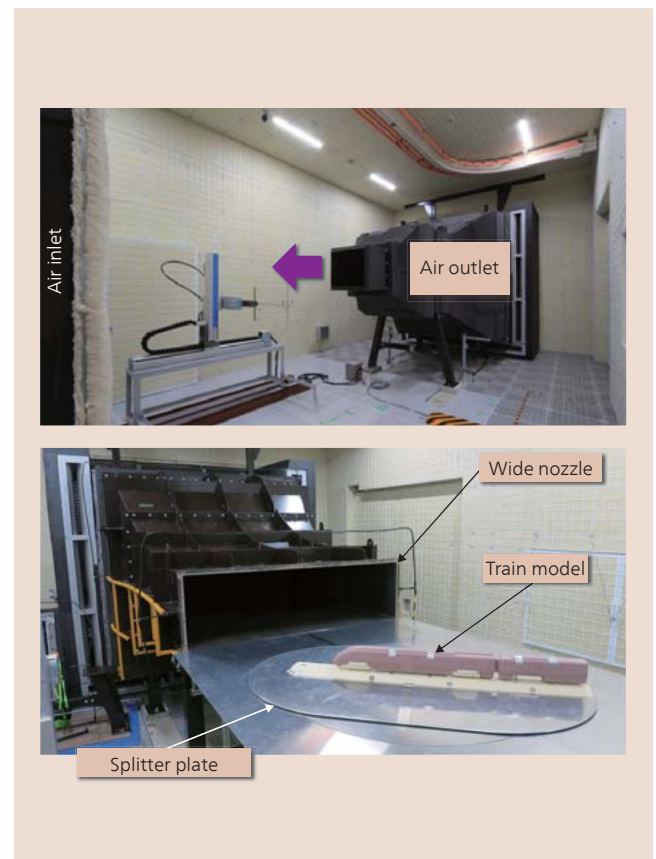
13 Measurement chamber of new wind tunnel (anechoic chamber) (top) and rolling stock safety test apparatus (bottom)
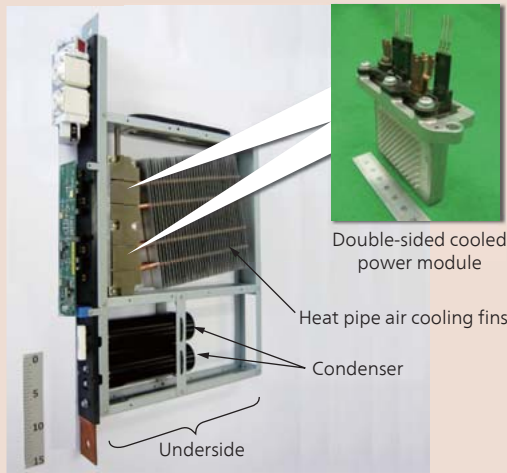
14 Modular power conversion unit (left) and double-sided cooled power module (right)

14 Technology for Reducing the Size of Industrial Power Converters Using Double-sided Cooled Power Modules

Using double-sided cooled power modules to achieve excellent cooling performance, Hitachi has developed standard modular power conversion units that can be fitted into a variety of systems.

The main requirements in the development of power converters over recent years have included making equipment smaller in order to save space and reducing maintenance times in order to increase equipment utilization. By using low-volume double-sided cooled power modules, which have superior heat dissipation compared to the power modules with single-sided cooling that were used in the past, Hitachi has succeeded in making its power conversion units smaller while also standardizing the main circuit components across different models. By using a proprietary heat dissipation system that runs heat pipes with excellent thermal transfer characteristics across both sides of the power modules for double-sided cooling, the newly developed modular power conversion unit halves the volume of the fins compared to previous models, allowing a thin 5-cm-wide design that facilitates side-by-side installation.

The modular power conversion units have been used in the development of a new generation of uninterruptible power systems (UPSs), providing easier maintenance when replacing parts and achieving a 30% smaller volume than previous Hitachi UPSs.

15 Double-sided FSW

Friction stir welding (FSW) is a method used for joining materials that works by inserting a rotating cylindrical tool between the materials to be joined, and running it along the seam of the joint. The heat generated by friction between the tool and the materials causes them to soften, and the rotation of the tool causes the materials to mix, thereby forming a weld.

One feature of double-sided FSW is that it sandwiches the materials to be joined between convex and concave tools. Because the gap between the tools and their respective directions and speeds of rotation can be chosen at will, double-sided FSW can also weld more quickly than conventional FSW, and can be used to weld thin sheet metal of 1 mm thickness or less. Its most important feature, however, is that it does not leave any regions unwelded, making the weld less likely to fail under complex loads that combine both bending and tension. Because this makes it possible to roll the welded material, the technique is suitable for welding machines used to achieve continuous rolling.

The technique is currently being considered for use in a metal forming machine for aluminum alloy plate at Mitsubishi-Hitachi Metals Machinery, Inc.
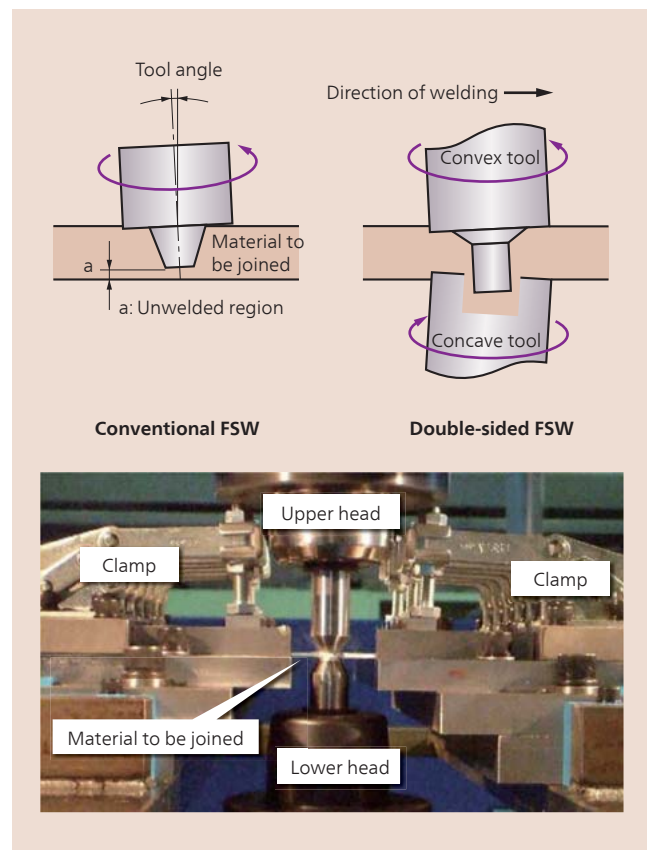
15 Diagram of welding process (top) and welding in progress (bottom)
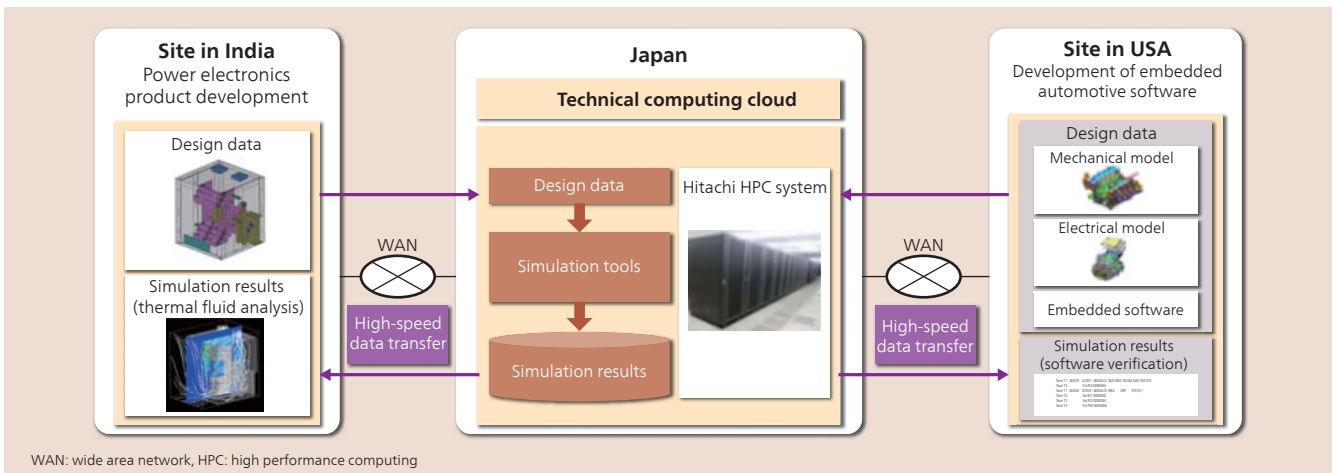
16 Design cloud configuration

16 Core Technology for Making Japanese Technical Computing Environment Available to Overseas Users

When undertaking design, development, and research work at overseas sites, it is important to ensure the reliability and other performance factors of overseas products, and this requires that the same level of design and technical computing environment be provided as is available in Japan.

This has led Hitachi to develop core technology for providing overseas design, development, and research sites with a similar level of access to a Japan-based technical computing environment such as supercomputers, etc. (the design cloud) as is available to Japanese users. By combining Hitachi's network acceleration and engineering data compression technology, this achieves communications more than 100 times faster than before, not only over the wide-bandwidth connection between facilities in Japan and the USA, but also over the narrow-bandwidth link between Japan and India. This enables the technical computing environment located in Japan to be used from other countries such as the USA and India.

In the future, Hitachi will proceed with the global standardization and consolidation of IT and business systems at design, development, and research divisions by testing and implementing this environment in other countries around the world.

17 Tri-axial Testing Technique for Emulating the Fatigue Phenomenon that Occurs on Structures during Operation

The complex loads that occur on transportation machinery, etc. during operation accelerate the fatigue phenomenon in their mechanical structures. To elucidate the fatigue phenomenon with complex loads, Hitachi has developed a testing technique that can emulate the stresses (in-plane stresses) that are generated on the machinery surface where fatigue failure occurs.

Since in-plane stresses consist of three stress components, a major feature of the new technique is its ability to emulate any in-plane stress, thanks to a design that allows loads to be applied independently in three different directions (0°, 45°, and 90°). By using one-sided actuators to simplify control and linear guides to prevent interference between different axes, the technique is able to generate maximum stress in the center of the test specimen. When used to emulate complex stresses measured on construction machinery during operation, the new technique was able to do so with an error margin of less than 3%. In fatigue testing, it was found that fatigue failure occurred at the evaluation point.

In the future, Hitachi will contribute to the development of highly reliable products for the social infrastructure sector by devising techniques for predicting with high accuracy the fatigue phenomenon with complex stresses that are generated on structures during operation.
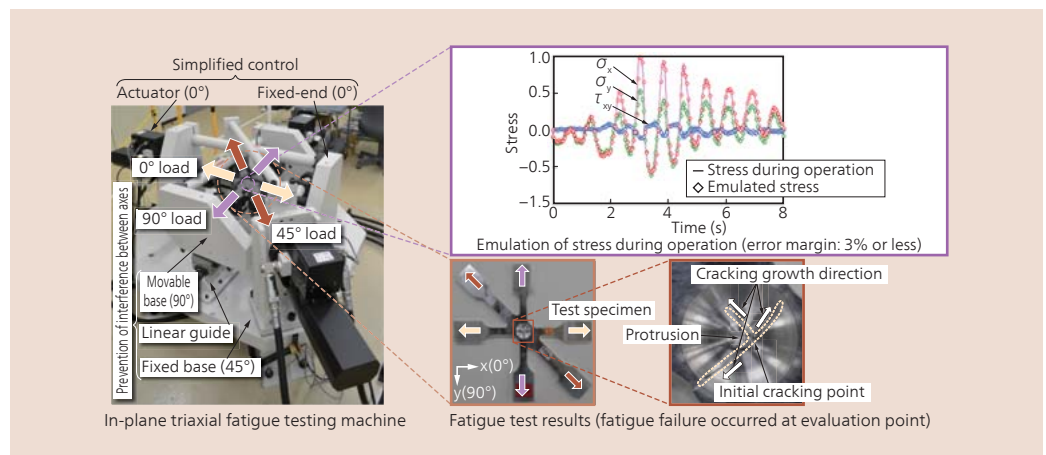
17 Emulation of fatigue phenomenon that occurs on structure during operation

Research & Development
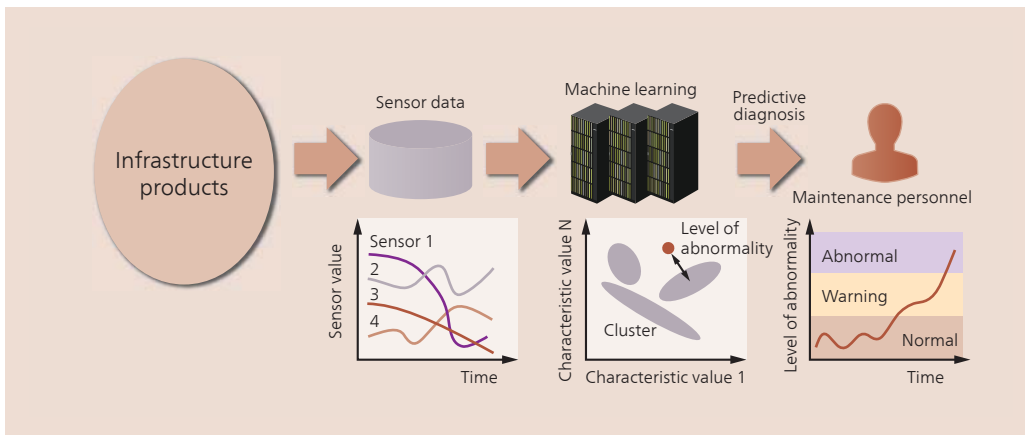
18 Use of machine learning to enhance maintenance services for infrastructure products

18 Analytic Technique Used by Maintenance Service for Infrastructure Products

In order to provide more advanced and efficient maintenance services to meet the requirements of infrastructure products, particularly in emerging economies, Hitachi has developed the vector quantization clustering (VQC) predictive diagnosis technique based on machine learning.

The technique can help with preventive maintenance because of its ability to detect abnormalities in products with greater accuracy than the previous practice of using individual threshold criteria for each type of sensor data. To assess product condition, the technique learns normal behavior in the form of clusters for each state, and then converts the relationship between cluster and current state into a single abnormality metric.

The fast processing speed of the newly developed technique means that on-board diagnosis can be built into the product itself, making it suitable for situations that lack reliable communications. It is possible to provide maintenance services that are tailored to individual products while also performing centralized management of a wide variety of infrastructure products by linking to the cloud.

## 19 Use of 3D Video Analysis for Human Behavior Analysis

Services that identify new value by measuring the movement and other behavior of people in spaces such as offices or shopping complexes have attracted interest in recent years.

Now, Hitachi has developed a technique that uses 3D analysis of video from stereo cameras to analyze human behavior. Past techniques for analyzing video from mono cameras suffered from significant reduction of recognition performance under certain imaging conditions. Because it can obtain 3D information about the captured scene by using the left and right stereo camera images to determine distance, the new technique can be used for applications such as detecting and tracking individuals, estimating the number of people, or identifying particular types of behavior. By using 3D information to improve the robustness of tasks such as position measurement or differentiating between different people, it can more reliably measure human behavior.

In the future, Hitachi will continue to contribute to the supply of solutions with high added value, such as the use of human behavior analysis for improving productivity or for security systems at stores or offices.
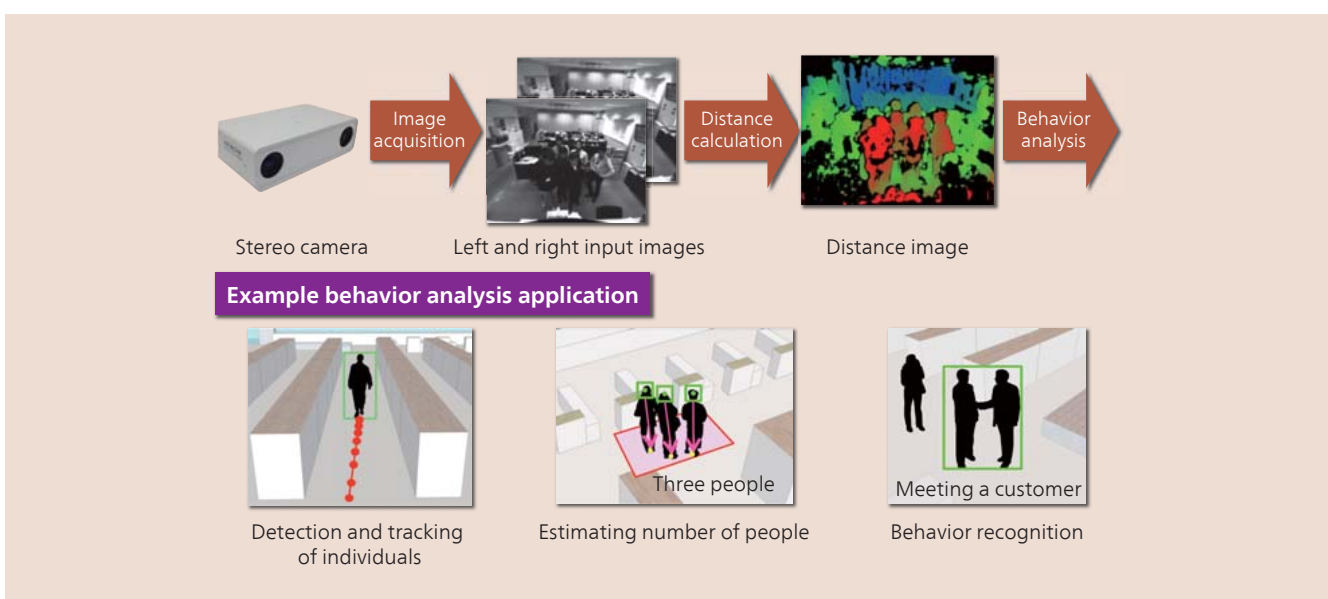
19 Behavior analysis application using stereo cameras
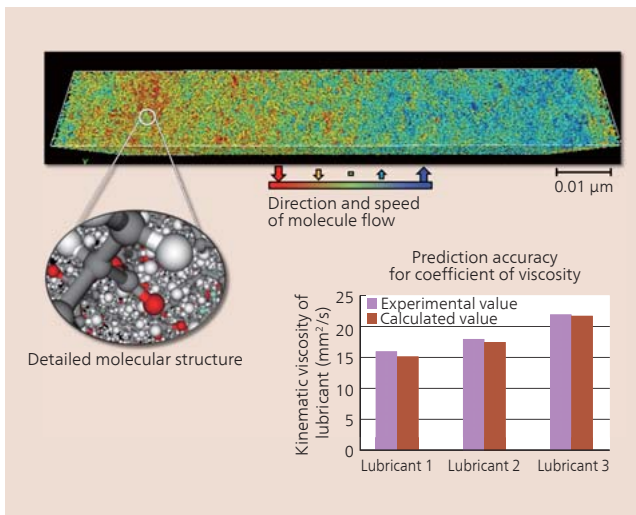
20 Use of molecular-scale flow calculations for lubricant to elucidate phenomena and predict properties

LAN: local area network, PC: personal computer, EBG: electromagnetic band gap

21 Radio direction finder

20 Large-scale Molecular Simulation Technique for Predicting Lubricant Properties in Sliding Parts

Amid worsening energy problems, reducing the energy losses in the sliding parts of drive machinery is an important concern. Practices adopted to achieve this include improving the quality of sliding surfaces and appropriate selection of lubricants and additives. The ability to visualize the molecular-scale flow behavior of a lubricant on sliding interfaces (regions in the order of 0.01 μm to 10 μm at the interface between sliding surfaces and lubricant) is also useful when designing for higher levels of energy efficiency.

Using a supercomputer, this newly developed technique is able to predict how the physical properties of a lubricant vary in response to environmental factors such as the pressure or temperature at the interface between sliding parts by visualizing sliding interfaces that are difficult to observe experimentally. The kinematic viscosity of lubricant calculated using the technique agreed with experiment to an accuracy within 10%.

In the future, Hitachi will analyze detailed molecular structures with the aim of making more appropriate material selections by predicting the properties not only of lubricants on sliding interfaces but also the effect of mixing them with additives. Hitachi will also contribute to product design and shorter development times by seeking to elucidate the phenomena that occur at the sliding interface.

21 Technique for Identifying Direction of Incoming Radio Waves

The spread of smart communities in recent years has seen increased use made of wireless communications for data collection and management services that use the collected data. Accordingly, a need has emerged for techniques that can identify the location of noise sources at installation sites in order to minimize interference between radio devices and provide uninterrupted wireless communication services.

In response, Hitachi has studied how the human eye determines the direction of incoming light rays and has developed a
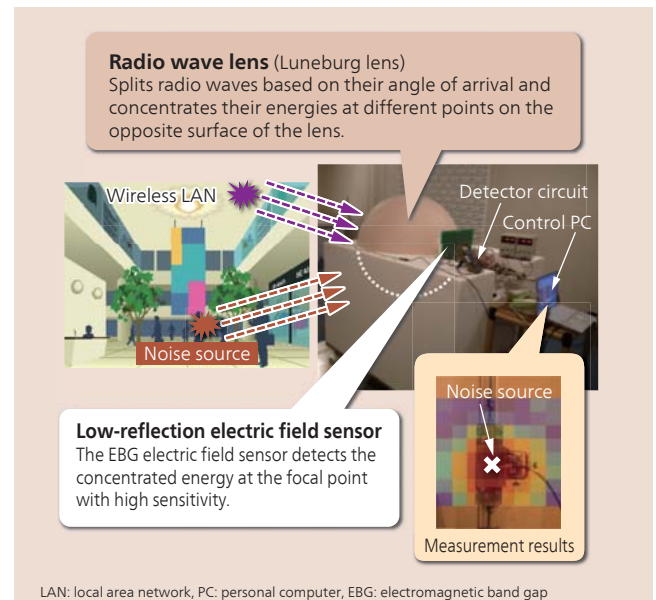
technique for identifying and displaying the location of radio sources that consists of a radio wave lens (Luneburg lens) that functions in a similar way to the lens of an eye, and an electric field sensor that acts like the retina. A Luneburg lens focuses at a different point depending on the direction of arrival of incoming radio waves, and the technique uses this property to achieve a high sensitivity of –65.6 dBm/m² by concentrating the weak radio energy at the focal point. It also achieves high angular resolution of 2.54° by positioning a low-reflection electric field sensor consisting of a tiny metal cell at the focal point.

In the future, Hitachi intends to test the technique at actual radio installations with the aim of improving the reliability and safety of the social infrastructure that incorporates wireless communications.

22 Business Dynamics

The changing background of market globalization and cross-industry mergers and acquisitions (M&A) has placed a growing importance on rapid decision-making in business. However, this decision-making is complicated by ongoing changes associated with the interaction between a variety of different factors in the environment in which people operate.

Business Dynamics* is a way of identifying the structures that give rise to these changes. It is a technique for identifying changes in advance by using a business structure model of the cause and effect relationships between the factors that influence business to determine structural characteristics.

The business structure model collates information that can be viewed from a variety of different perspectives, including customer data, publically available data, and information from customer interviews, and represents it as a type of directed graph known as a causal loop diagram (CLD). Because of the large and complex structure of a CLD, Hitachi has developed a function that uses pattern matching techniques to automatically identify issues. It

Research & Development
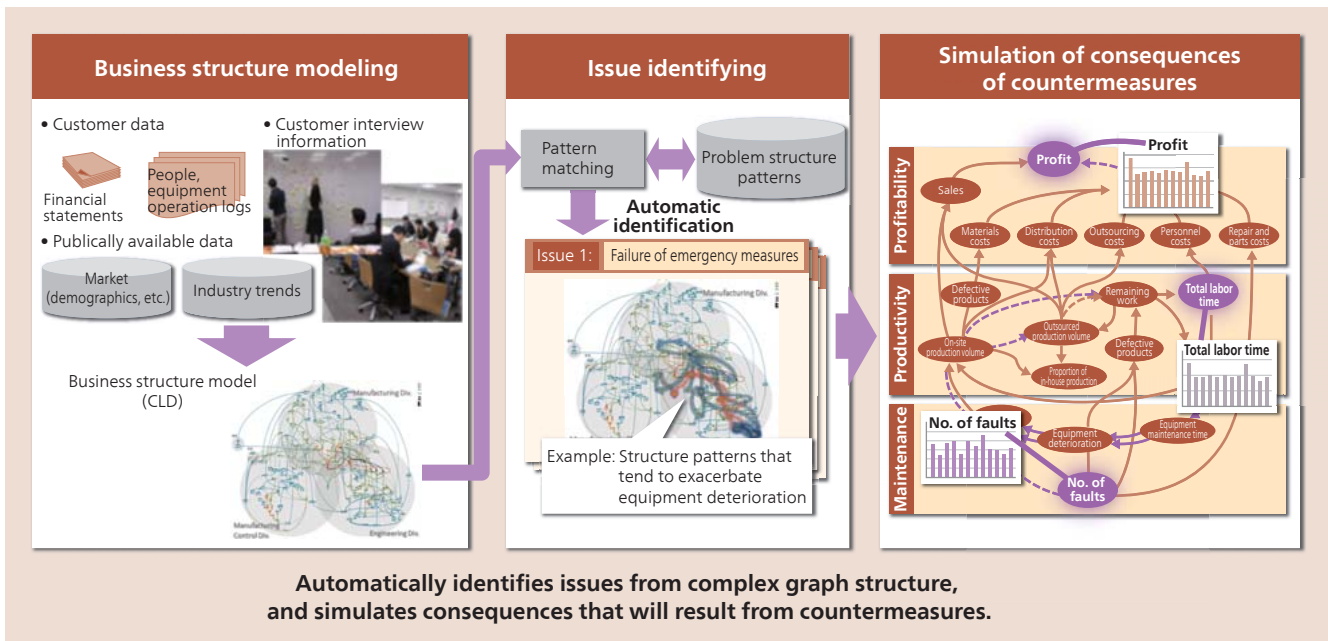
22 Sequence of steps in business dynamics analysis

also performs quantitative simulations of what flow-on changes will arise from the measures used to deal with the identified issues in order to determine when and to whom consequences will result, and whether they will turn out to be counterproductive.

Although this technology has been applied in about 30 cases up until now, including manufacturing, finance, logistics, and power generation, Hitachi intends to brush it up based on actual applications in the future.

* Developed by Massachusetts Institute of Technology (MIT) in the USA. Hitachi has rich experience in applying this technique and, with the unique know-how to apply this technique quickly and easily, it is developing software and templates for each industry, etc.

23 Installation Support System for Commercial Air Conditioners

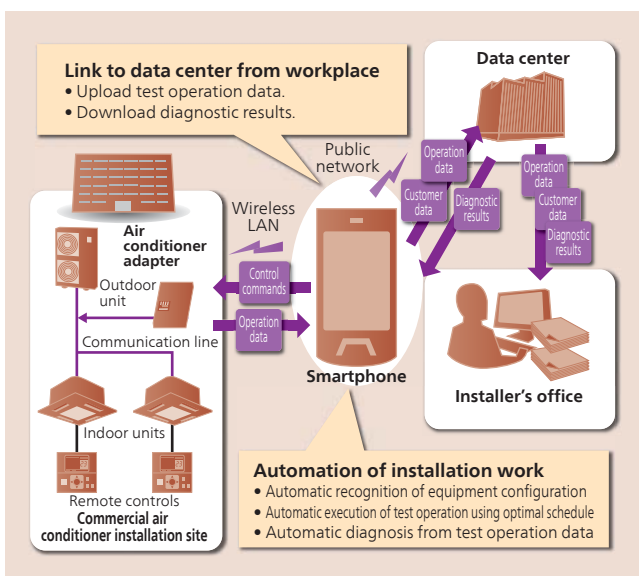Commercial air conditioners consist of indoor units, outdoor units, and remote controls. A major obstacle to reducing the cost of installation is the difficulty of performing the work efficiently without having specialist knowledge.

Given this situation, Hitachi is developing an installation support system for commercial air conditioners that facilitates installation work by using air conditioner adapters to connect to a communication line for commercial air conditioners, and integrating smartphones that act as general-purpose interfaces.

The system simplifies each step of the work by automating such activities as recognizing the configuration of multiple air conditioners, executing test operation in accordance with an optimal schedule, and performing diagnosis from test operation data, and is able to do so by using a smartphone as a relay for linking to a data center from the workplace if the commercial air conditioner itself is unable to get a network connection to the data center. This can help make installation by workers who lack specialist knowledge more efficient.


23 Installation support system for commercial air conditioners that uses smartphones and air conditioner adapters

24 Camera Technology for Instantaneous Correction of White-out due to Bright Light

Growing concern for public safety and security in recent years has created demand for surveillance cameras to provide clear images even under conditions that make it difficult to see what is happening, such as in darkness or when reflections are present.

Now, Hitachi has developed technology for enhancing visibility that can cope with difficult conditions with strong backlighting, such as headlights or headlight reflections in the dark, by combining instantaneously adjusting exposure techniques, noise reduction techniques, and contrast stretching techniques that make dark regions appear less dark. By instantaneously adjusting exposure to reduce white-out and performing correction without using the composition processing techniques used in the past, the technology can produce clear images with a processing time of no more than 0.23 s even when a bright object appears suddenly in
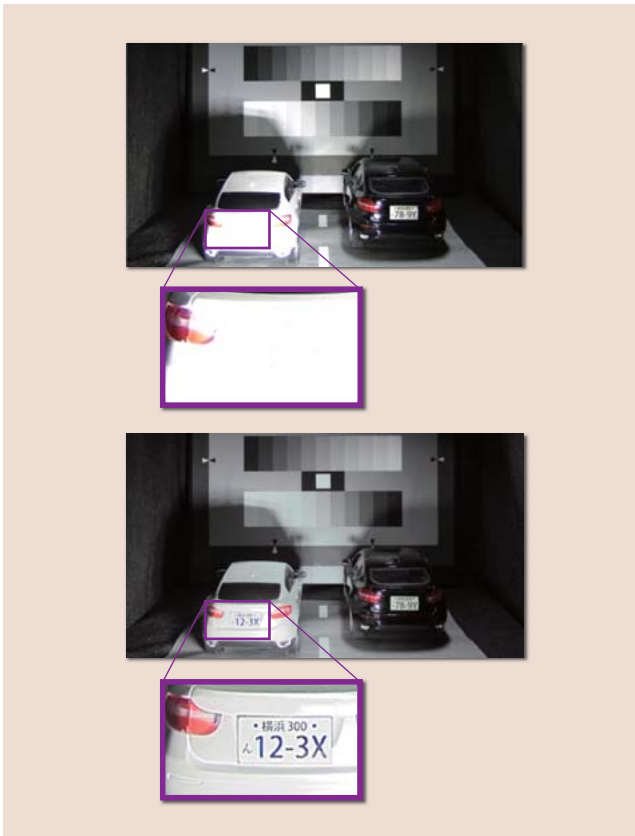
24 Comparison of uncorrected image (top) and image after performing instantaneous correction for white-out without blurring (bottom)

25 Overview of how molecularly imprinted polymer is manufactured (top) and fluorescence microscope image of fluorescent labeled cortisol (whiter regions have a higher level of fluorescence) (bottom)

the shot.

The technology is included as one of the functions on the surveillance camera modules supplied by Hitachi Industry & Control Solutions, Ltd. to markets in North America and Europe (released in September 2014).
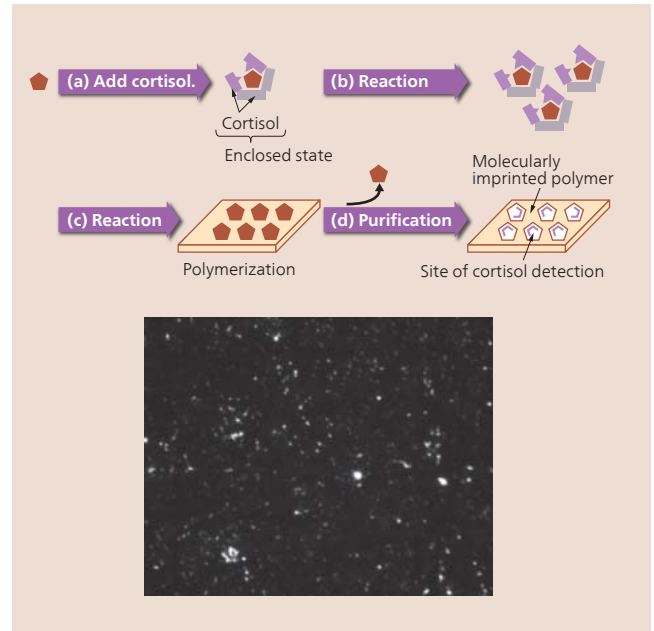
In the future, Hitachi intends to build surveillance cameras and video surveillance solutions that can provide clear video images by making further improvements to contrast stretching and noise reduction techniques.

25 Manufacturing Technique for Molecularly Imprinted Polymer Used in Testing Kits for Stress-related Hormones

Hitachi has developed a manufacturing technique for a molecularly imprinted polymer that is able to detect cortisol, a stress-related hormone, with high sensitivity.

A molecularly imprinted polymer has a surface that is specially designed to recognize a particular target molecule based on its physical structure and other properties (a polymer is a high-molecular-weight material formed from many molecules linked together). In developing the manufacturing technique for the molecularly imprinted polymer, which has excellent recognition ability, Hitachi's aim was to enable the point-of-care testing of cortisol.

Achieving the point-of-care testing requires a method for determining whether cortisol has become bound to Hitachi's manufactured polymer. To achieve this, Hitachi also established a technique for synthesizing cortisol with a fluorescent labeled molecule, which is a known method for achieving highly sensitive
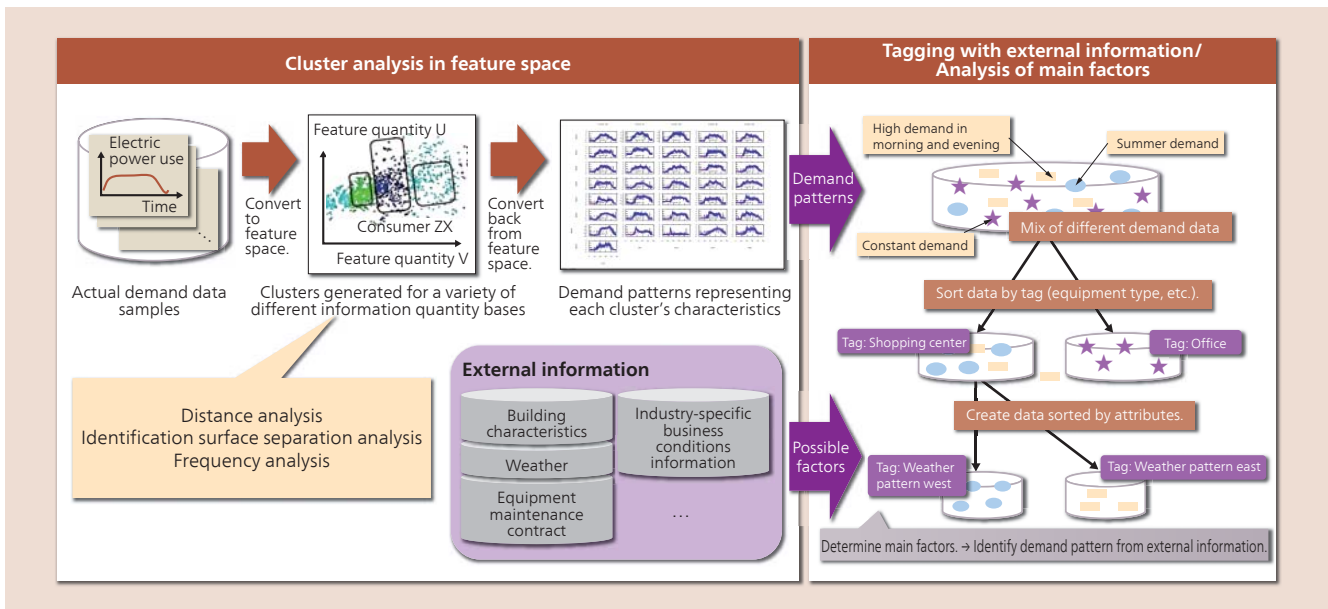
detection. Combining the fluorescent labeled cortisol with the molecularly imprinted polymer provides a quantitative indication of how much cortisol has bound to the polymer.

Because the new technique can detect cortisol with high sensitivity and without the need to separate protein antibodies from living organisms and purify them, as in the past, it opens up the potential for commercializing a kit for the point-of-care testing of stress-related hormones in saliva.

26 Electricity Demand Analysis Technique

In readiness for the comprehensive liberalization of the Japanese electricity retail market beginning in 2016, the companies that produce and sell electric power are expected to offer a range of billing options that suit the different types of consumers around the country, and that make economic sense while also promoting energy efficiency without imposing a burden. Rather than just broadly classifying demand into industrial and residential, achieving this requires analysis of the actual characteristics of electricity demand (when and how much).

The electricity demand analysis technique converts actual consumption data into feature space data and generates clusters from data with similar characteristics over time periods of between several tens of minutes and an entire year. By determining the dimensionality of the feature space and the number of clusters according to a variety of different information criteria, good-quality demand patterns that represent just enough of the demand characteristic can be obtained from the clusters. It is also possible to use external demand information to perform a simple analysis of electricity demand for consumers from outside the sample by tagging the external information for the samples that belong to each cluster and using this information to analyze the main factors involved in demand pattern generation.

Cluster analysis in feature space

Tagging with external information/
Analysis of main factors

Electric power use / Time

Actual demand data samples

Convert to feature space.

Feature quantity U
Consumer ZX
Feature quantity V

Clusters generated for a variety of different information quantity bases

Convert back from feature space.

Demand patterns representing each cluster's characteristics

Distance analysis
Identification surface separation analysis
Frequency analysis

External information

Building characteristics
Weather
Equipment maintenance contract

Industry-specific business conditions information
…

Demand patterns

High demand in morning and evening
Summer demand
Constant demand
Mix of different demand data

Sort data by tag (equipment type, etc.).

Tag: Shopping center
Tag: Office

Create data sorted by attributes.

Possible factors

Tag: Weather pattern west
Tag: Weather pattern east

Determine main factors. → Identify demand pattern from external information.

26 Electricity demand analysis technique

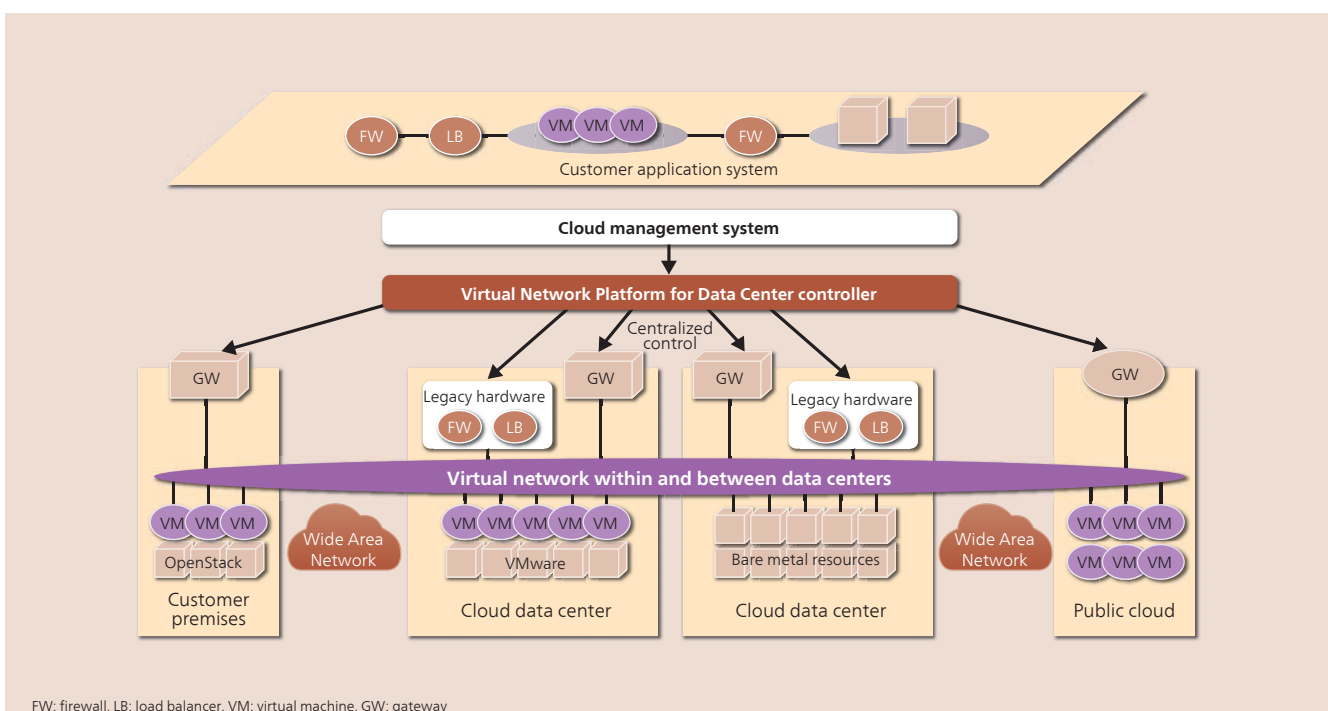## 27   SDN Technology for Cloud Data Centers

Software-defined networking (SDN) (virtual networking with centralized control) is increasingly being recognized for its potential to reduce the workload and risk of human error associated with manually performed network configuration changes at cloud or other corporate data centers. In the past, however, SDN has only been available at data centers equipped with hardware that complies with new standards such as OpenFlow* or that used server virtualization from a specific vendor.

The new SDN technology for cloud data centers developed by Hitachi, on the other hand, is able to provide centralized control of a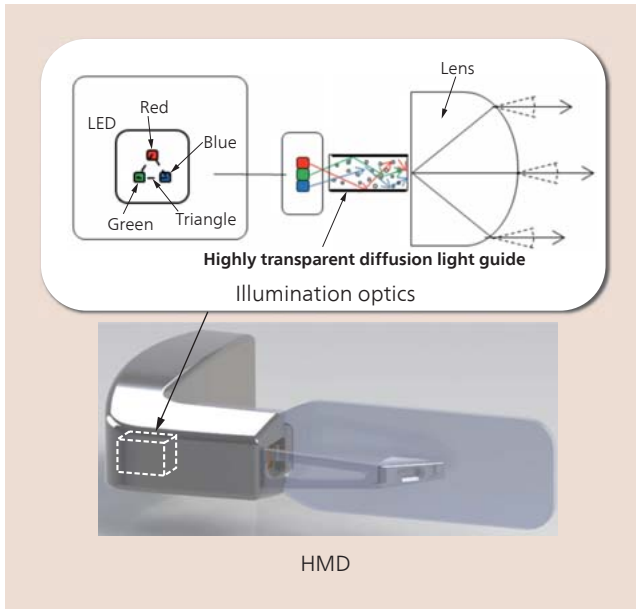 wide variety of legacy hardware through the abstraction modeling of firewalls, load balancers, and other devices. It also implements flexible virtual networks that are not dependent on the server virtualization technology by performing centralized control of gateways that encapsulate communications to provide connections between data centers or between clouds. This provides a way to automate network configuration changes that previously took anywhere from several hours to several days in environments that contain legacy hardware systems and multiple data centers or clouds of different types.

These new technologies will be progressively rolled out in the Virtual Network Platform for Data Center (VNP-DC) software of Information & Telecommunication Systems Company, Hitachi, Ltd.

* See "Trademarks" on page 146.

FW LB VM VM VM FW
Customer application system

Cloud management system

Virtual Network Platform for Data Center controller

Centralized control

GW   GW   GW   GW
Legacy hardware
FW LB
Legacy hardware
FW LB

Virtual network within and between data centers

VM VM VM   VM VM VM VM VM   VM VM VM
OpenStack   Wide Area Network   VMware   Bare metal resources   Wide Area Network   VM VM VM

Customer premises   Cloud data center   Cloud data center   Public cloud

FW: firewall, LB: load balancer, VM: virtual machine, GW: gateway

27 SDN technology for cloud data centers

28 Multiple refraction light guide

28　Small, High-brightness Optical Engine for HMDs

The increasing complexity in recent years of tasks in production line, maintenance management, stocktaking, and other work environments has led to demand for improving productivity and reducing errors. To achieve this, it is important for workers to share information and issues in their workplace with managers in realtime. This has led to interest in the use of head-mounted displays (HMDs) that can be used for hands-free information sharing that does not interrupt the work being done. However, considering factors such as working hours and use in outdoor work, these HMDs need to be able to operate continuously for eight hours and provide sufficient brightness to be read in 100,000-lx direct sunlight.

The new optical system that Hitachi has developed for HMDs combines high optical efficiency with uniform brightness achieved by superimposing reflected light. It achieves eight times* the optical efficiency of competing products thanks to its low-loss optics, which use a high-order aspherical lens and an industry-first* highly transparent diffusion light guide jointly developed by the Yokohama Research Laboratory of Hitachi, Ltd. and Hitachi Chemical Co., Ltd. This makes it possible to build an HMD with both low power consumption and a display that is easy to read even under outdoor conditions.

In the future, Hitachi intends to undertake trials of HMDs fitted with the new optical system in collaboration with application users, and to deploy the technology in a wide range of fields.

* Based on research by Hitachi, Ltd.

29　Thermoelectric Conversion Module Able to Withstand High Temperatures

Thermoelectric conversion works by converting waste heat from power plants, factories, vehicles, or other sources into electric power. Despite rarely ever being used in the past, it has attracted
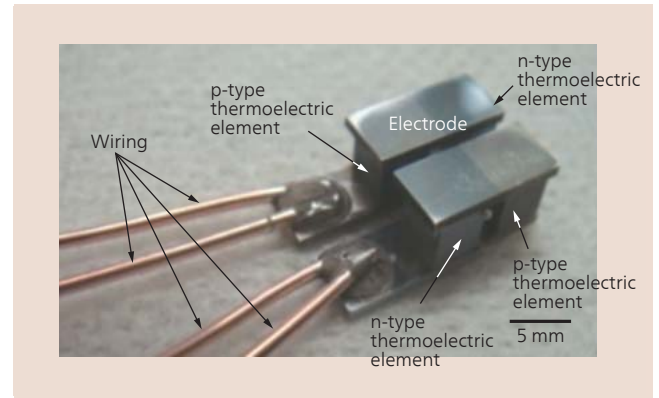
29 Two-pair thermoelectric conversion module

attention as a way of generating electric power that is environmentally conscious.

While the generation efficiency of a thermoelectric conversion module increases the greater the difference in temperature is between its top and bottom surfaces, the major challenge when operating at high temperatures is how to ensure the reliability of the joints between the thermoelectric elements and electrodes. Accordingly, Hitachi has investigated a highly reliable bonding technique that uses aluminum as the bonding material.

One feature of the technique is that it causes the aluminum to form intermetallic compounds during the bonding process so the joint will not melt again even if the temperature subsequently reaches the melting point of aluminum (933 K). When Hitachi used the newly developed technique to build a prototype two-pair thermoelectric conversion module made up of four elements, it demonstrated a joint strength four times the previous method and generated an output of 1,000 mW at 923 K. It is anticipated that this will provide a major boost to the commercialization of thermoelectric conversion modules that can be used at high temperatures.

Hitachi intends to continue with structural optimization and other enhancements in order to develop highly efficient modules with a view toward a product release.

30　Automatic Malware Analysis Techniques for Multiple Environments

Recent years have seen increasingly frequent cases of organizations being infected by malware that cannot be detected by existing measures. In such cases, it is necessary to identify the characteristics of the malware and quickly implement countermeasures to prevent further losses. One method used to identify malware characteristics is dynamic analysis, whereby the malware is run on a special analysis system to observe its behavior. In the case of recent malware, unfortunately, an increasing number are of a type that evades analysis by only running in certain environments.

This has led to the research and development of techniques for analyzing malware in a variety of different ways by using a number of different types of dynamic analysis environments. When implementing the environments, published vulnerability information, attack patterns, and so on are used as a basis for selecting those

Research & Development

135
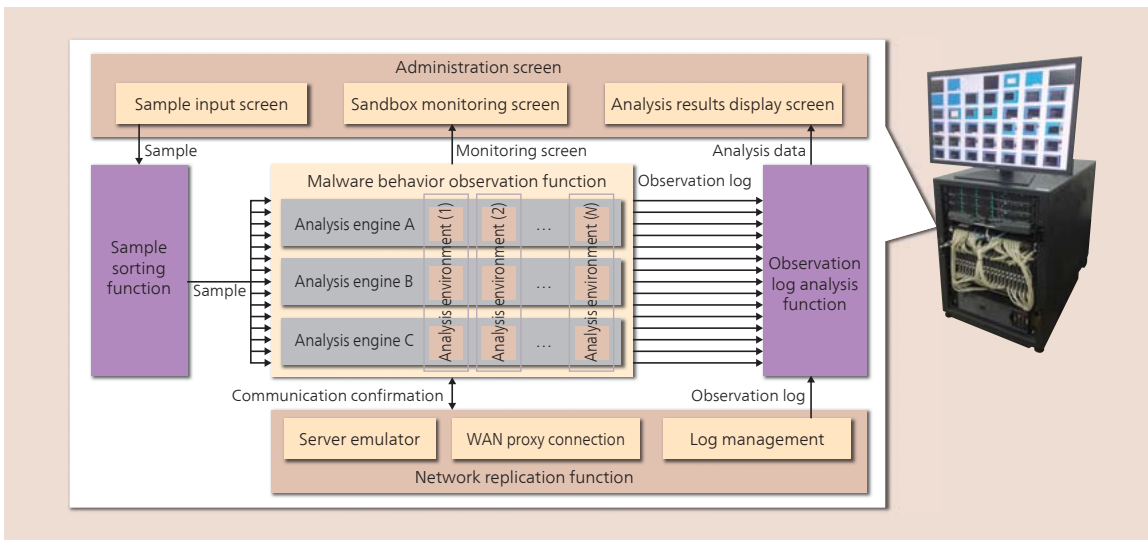
30 Dynamic malware analysis system for multiple environments and an overview of its functions

environments in which it is easy to get the malware to run and to observe its behavior. Hitachi has also developed a technique for automatically identifying malware behavior from observations by incorporating its know-how about malware analysis into scripts. By simplifying the identification of network connections or other unauthorized actions by the malware, the technique helps avoid losses and helps prevent them from being exacerbated.

31 Big Data Platform for Large Quantities of Time Series Data

There is growing demand for the use of large quantities of time series data such as the analysis of sensor data made possible by the spread of the Internet of things (IoT). Hitachi has now developed a big data platform that can collect large quantities of time series data as it is generated and make it available for immediate retrieval.

The new platform technology temporarily stores the data coming in with high frequency in in-memory cache before loading it in blocks into the ultrafast database engine*. This

enables both high-speed loading and immediate retrieval of stored data (loading of one million or more items per second of sensor data collected at intervals of a few seconds, and retrieval of required historic data with a retrieval time of a few seconds). The database engine also has a function for accessing archived data using a single structured query language (SQL) query. These features have reduced the cost of storing large quantities of sensor data by an order of magnitude.

Hitachi is currently working on incorporating the newly developed platform into a wide-area power grid monitoring system targeted at overseas grid operators. As it works toward commercialization, Hitachi intends to market systems to customers and continue enhancing the technology.

PMU: phasor measurement unit, PDC: phasor data concentrator
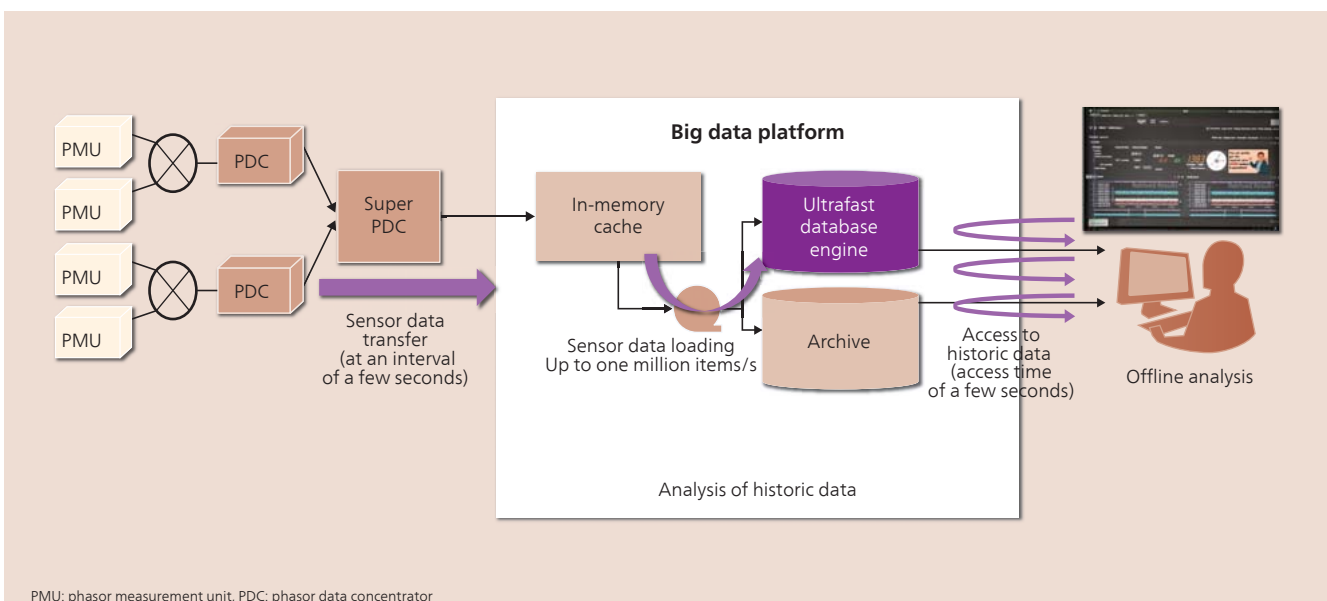
31 Big data platform
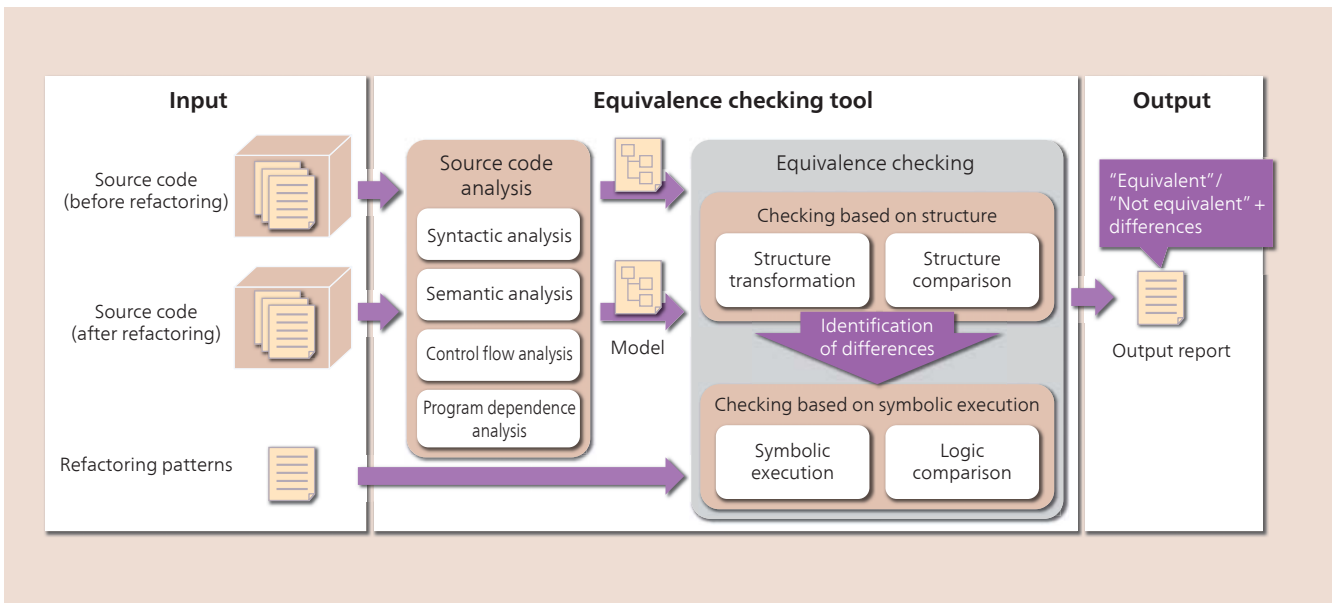
32 Program equivalence checking using symbolic execution

32 Program Equivalence Checking Technique

The key to efficient software development lies in keeping software structures clean. Accordingly, growing use is being made in product development of refactoring, which means improving program structures, to achieve this. However, changing a program carries a risk of introducing bugs, and this also applies to making structural improvements by refactoring.

In response, Hitachi has developed a technique for analyzing source code before and after refactoring to check whether the changes affect its behavior. The technique uses a method called symbolic execution to check the logical equivalence of the programs' inputs and outputs. To enable its use on large programs, it can efficiently narrow-down the checking scope by transforming and comparing structures according to refactoring patterns.

When deployed on server product software, the new technique was able to correctly check 75% of refactoring. This reduces the risk of bugs being introduced by refactoring and provides an effective way to make structural improvements to software in product development.

33 Innovative Manufacturing Process for Lithium-ion Batteries

Rapid growth in the use of lithium-ion batteries is driving demand from users for lower costs. One way to cut costs is to reduce the component count from that of the current electrode structure, which consists of three components: the anode, cathode, and separator.

In contrast, a newly developed fabrication process reduces the component count to two by coating the separator onto the electrodes. In the new fabrication process, separator slurry coating is performed immediately after electrode slurry coating, creating a layer in which electrode and separator are mixed. Since a short circuit between anode and cathode may occur if this mixed layer

becomes too thick, the challenge is to make the mixed layer thinner. Hitachi's new process succeeds in controlling the mixed layer thickness by optimizing separator coating pressure control and the composition of the separator slurry. As a result, it is able to keep the mixed layer of the combined separator and electrode thin enough that no short circuit will occur.

The new process has been implemented in a development system belonging to Hitachi High-Tech Fine Systems Corporation where it is being tested in readiness for commercialization.
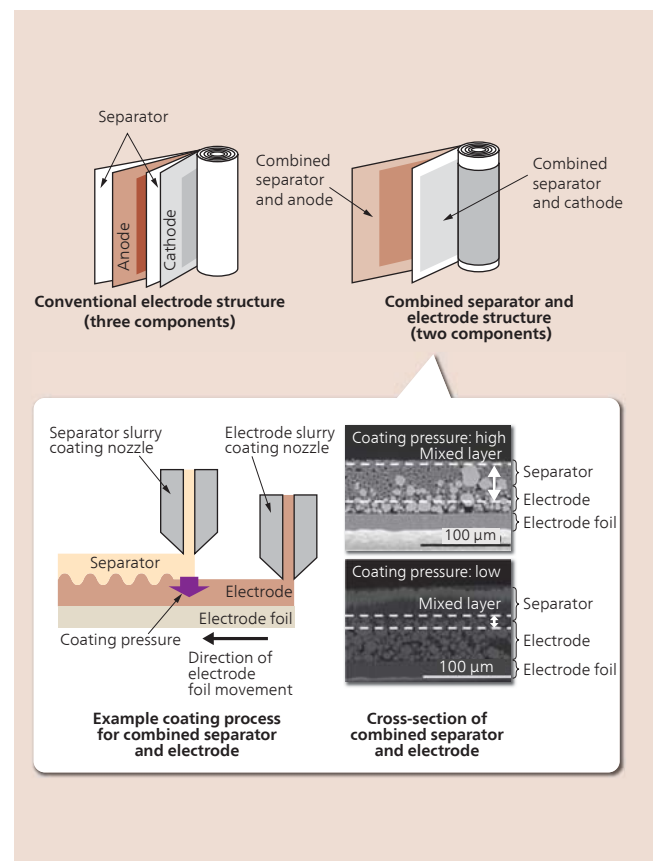
33 Comparison of conventional and new electrode structures, and example of new coating process together with electrode cross-section
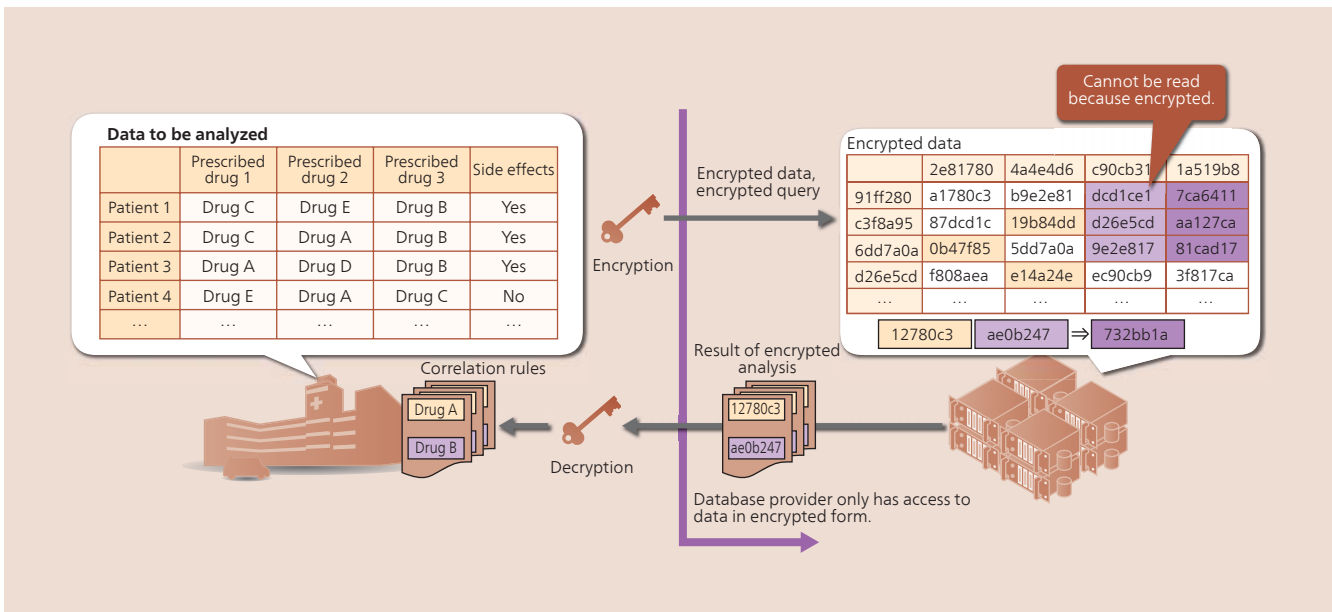
34 Configuration of confidential analysis system

34 Confidential Analysis Technique

Recent years have seen frequent cases in which large amounts of data, including confidential information, has been stolen from databases, creating an obstacle to the use of big data. While data encryption is one way of dealing with this, the problem is that analysis and other processing cannot be performed on encrypted data.

To overcome this problem, Hitachi has developed a confidential analysis technique that can perform tasks such as the analysis of basic statistics and correlation rules using searchable encryption, whereby comparisons can be performed on encrypted data without first decrypting it. In an experiment, correlation rule analysis was performed on 100,000 records of encrypted data in about 10 minutes, demonstrating that analyses can be performed in a realistic time frame. The technique can be used to perform analytical processing without revealing the original data to the database provider, enabling the data to be used in big data applications while also reducing the risk in the event it is stolen.

35 New Storage Virtualization Technology with Enhanced Availability

The increasing globalization of markets is creating a need for companies to deliver continuous 24-hour/365-day services, and this requires that storage systems achieve high levels of availability (uninterrupted operation).

Now, Hitachi has developed a new storage virtualization technology that makes multiple storage systems appear to servers as a single virtual device. This improves availability in the following two ways.
(1) Virtualizing legacy and new storage systems as a single device eliminates the need to shut down servers when making storage
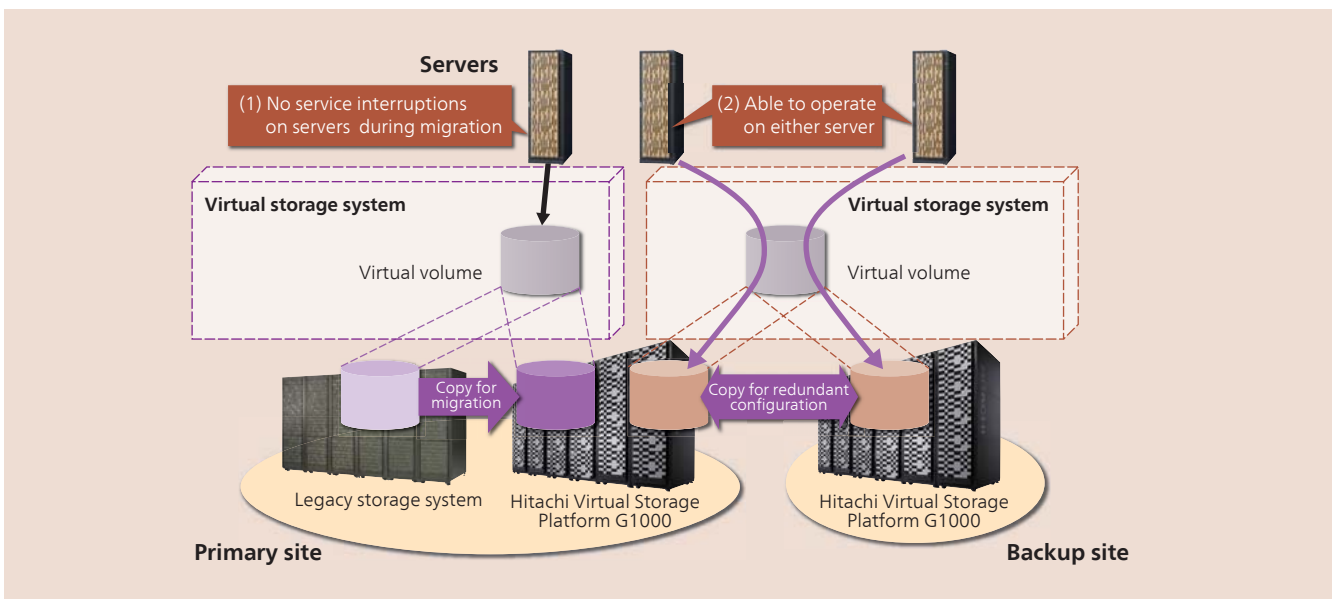
35 New storage virtualization technology

system changes, enabling migration to new systems to occur without any service interruption.
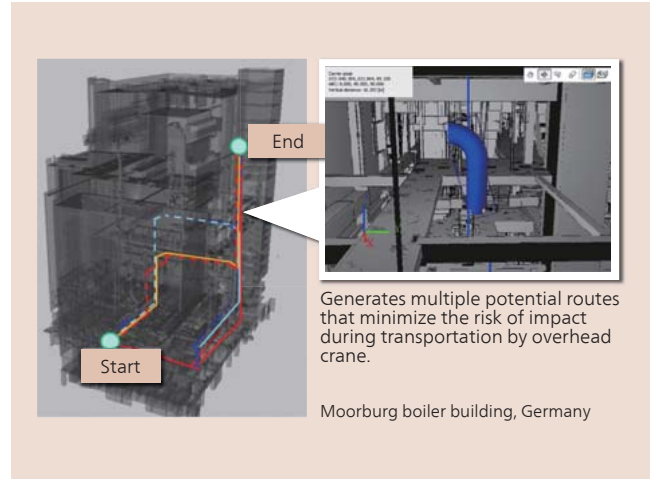
(2) In redundant configurations that duplicate systems across sites, virtualizing the storage systems at both sites as a single device enables routine operation to continue on the backup site servers and increases the speed of system switchover in the event of a fault or disaster.

The new technology has already been incorporated into the Hitachi Virtual Storage Platform G1000 enterprise storage system, and Hitachi plans to deploy it in mid-range storage in the future also.

36 Route Finding System for Transporting Industrial Equipment

Planning how to transport major items of equipment into and out of plants during maintenance and replacement tasks is expensive and time-consuming.

In response, Hitachi has developed a route finding system that uses three dimensional models of the building and equipment as inputs and uses a computer to automatically calculate the spatial requirements for avoiding collisions. This enables it to rapidly and automatically determine the route and orientation that minimizes the risk of collision between building and equipment to transport. This reduces the time taken to determine the route in the past from five hours to a single minute, and succeeded in reducing the installation costs for equipment replacement at an overseas coal-fired power plant (in 2013) by 25%. A feature of the route finding technique is that it performs prioritized optimization of multiple objective functions, such as the risk of collision and number of times the equipment needs to be switched from one crane rail to


Generates multiple potential routes that minimize the risk of impact during transportation by overhead crane.

Moorburg boiler building, Germany

36 Example use of route finding system for transporting industrial equipment

another.

In the future (2017), Hitachi plans to use the technique to generate routes that minimize contamination in the transportation of waste in nuclear power plant decommissioning and maintenance.

37 Public Biometrics Infrastructure (PBI) for Electronic Payments

As the volume of electronic payments over the Internet continues to increase, so do losses due to unauthorized transactions. Along with countermeasures against malware, the use of mutual authentication based on public key infrastructure (PKI), and digital signatures to prevent the falsification of transaction data also play
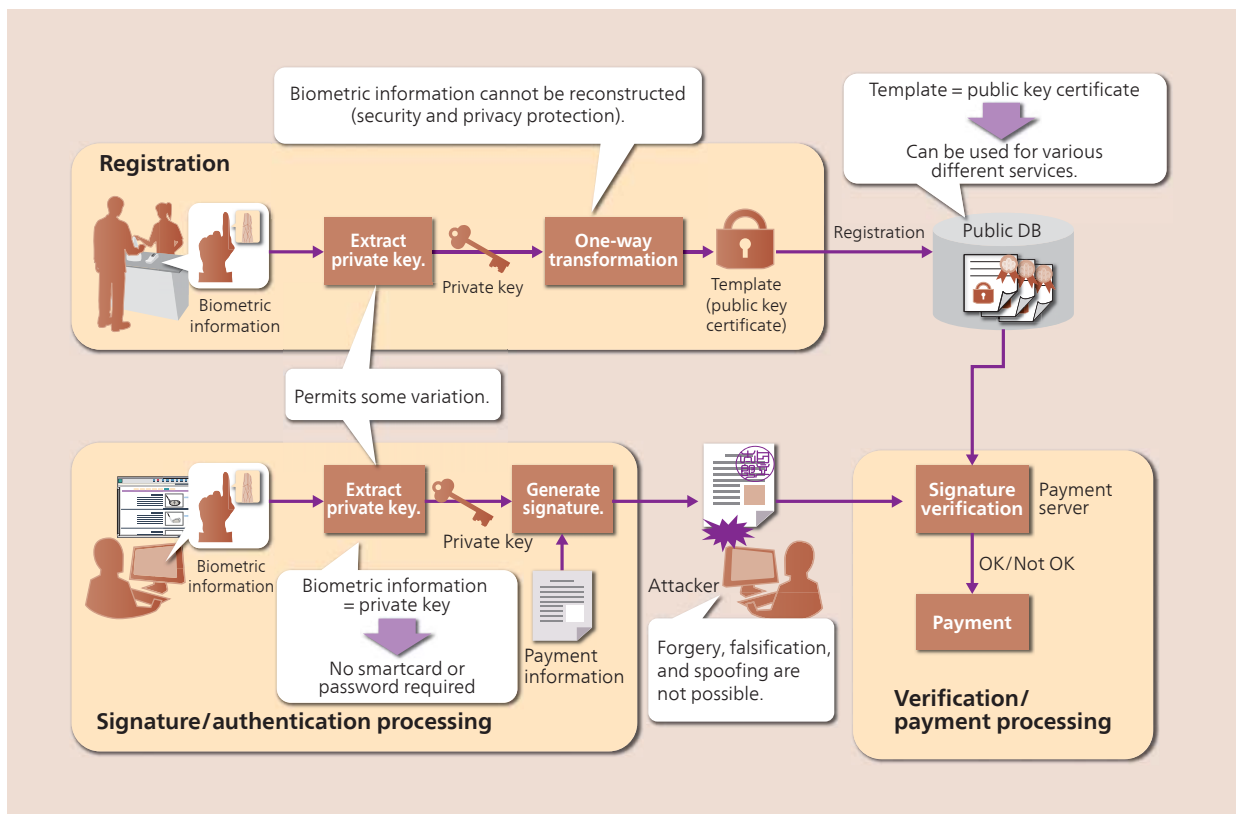
37 Secure and convenient electronic payments using PBI

important roles in preventing this. However, since key management requires the use of smartcards and hardware tokens, it incurs less convenience and increased costs.

Accordingly, Hitachi is pursuing the research and development of public biometrics infrastructure techniques that eliminate the need for key management by using biometric information such as finger vein patterns for the private key to realize convenient and low-cost implementations of PKI. Specifically, Hitachi has developed the algorithm for digital signature (biometric signature) technique that uses fuzzy data (such as biometric information) as its private key with mathematically provable security. It has also achieved a practical level of authentication accuracy (one in one million false acceptance, 0.2% false rejection) by developing a feature transformation technique that can take finger vein data and generate feature data with less error suitable for use in biometric signatures. The technology has been deployed in a finger vein authentication system and used to build a prototype electronic signature system for payments that uses finger vein information as the private key.

These results indicate the potential for using PBI to make secure and convenient electronic payments.

38　Business Process Modeling Technique Using Hierarchical Process Variation Analysis

Improving the quality of business requirement definitions during system development is important because errors in these defini-
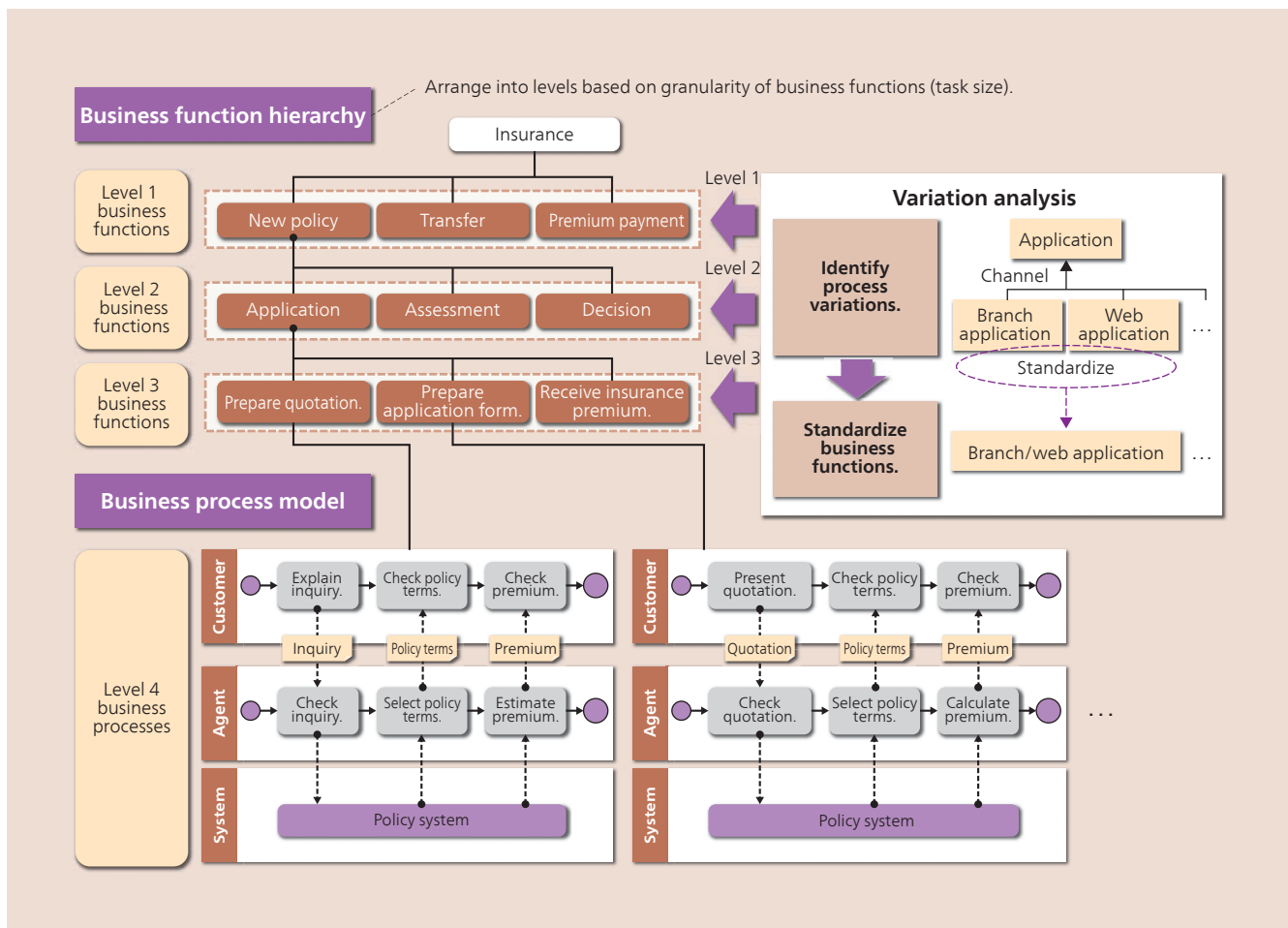
tions can lead to major cost increases in the downstream development processes. Business modeling, which represents business processes and defines their structure in the form of a model, is seen as a technique for achieving this. The problem with this is the large amount of work required to model complex business processes in industries such as finance.

In response, Hitachi has developed a labor-saving technique that focuses on process variations, one of the factors that causes modeling to require so much work. Specifically, the technique looks at the hierarchical structure of business functions and establishes perspectives for identifying process variations according to the granularity of each level so as to identify all process variations without missing any, thereby reducing the need for modeling rework. It also avoids the duplicated development of similar process models by looking at factors such as the information handled in each process and the role of the staff responsible in order to analyze the similarity of business processes and standardize similar business functions that result from process variations. When used in a system development project for an insurance company, the technique reduces the amount of work required for modeling by 30%.

In the future, Hitachi aims to further improve modeling productivity by collating business knowledge built up in projects that use this technique in the form of reference models.

38 Business process modeling technique using hierarchical process variation analysis