Value-based Innovation: Resilience

Currently, the environment in which companies operate is changing at an unprecedented rate, driven by rapid progress of digital technology as well as an increasing incidence of natural disasters, pandemics, and geopolitical risk. With these conditions making business resilience more important than ever for many customers, along with the maintenance and restoration of social infrastructure, there is an urgent need to build value chains that are robust, secure, and operationally efficient. To address customer challenges like these, Hitachi is engaged in research and development across a wide range of topics. These include a supply chain coordination service that synchronizes sales, production, procurement, and logistics across multiple sites and companies; measurement technologies for more efficient maintenance and management of aging social infrastructure; and labor-saving solutions that combine safety and efficiency in environments where people coexist with autonomous mobility.

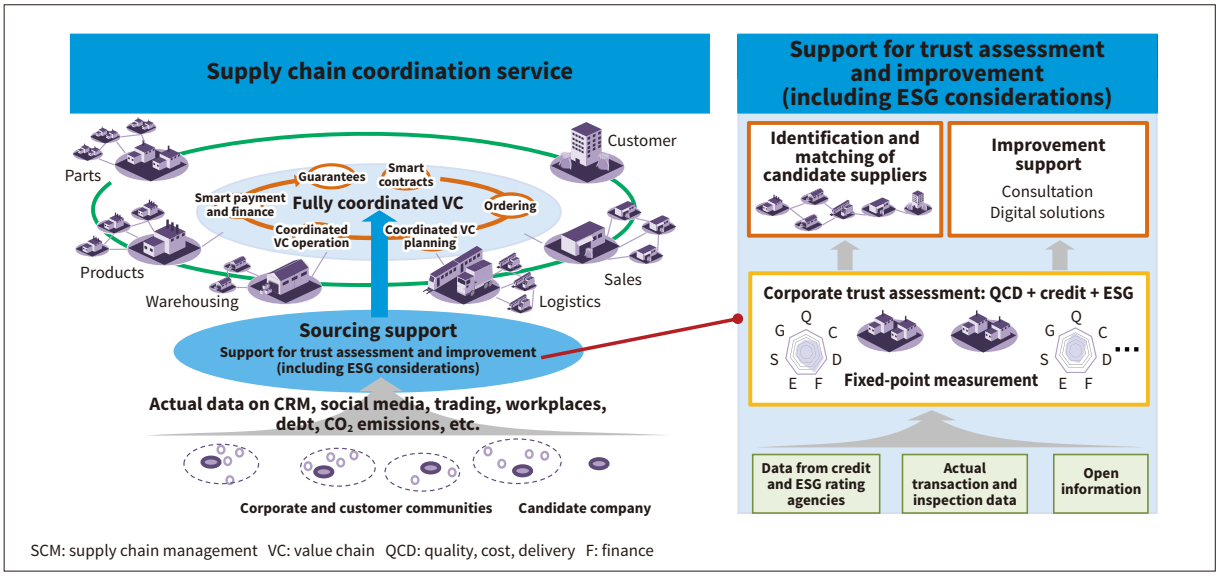
1 Supply Chain Coordination Service that is Both Robust and Operationally Efficient

As changes in consumer behavior force product ranges to expand in tandem with rising demand for rapid delivery, and with greater emphasis on environmental, social, and governance (ESG) values together with an increase in natural disasters and geopolitical risk, there is an urgent need for the manufacturing and logistics industries to redesign their supply chains to be both robust and operationally efficient.

In response, Hitachi is developing its concept of a supply chain coordination service that provides full value chain synchronization along with sourcing support.

Full value chain synchronization involves optimal planning and operational supervision to coordinate sales, production, procurement, and logistics across multiple sites and companies. Some elements of this are already available as part of Hitachi's TWX-21 service.

Sourcing support, meanwhile, provides assistance with the selection of suppliers through trust assessment that takes account of ESG considerations as well as the usual issues of cost, quality, delivery, and credit. This involves a multifaceted review of the trustworthiness of companies or particular sites based on real-time monitoring of actual data on things like transactions, inspections, debt, and carbon dioxide (CO_2) emissions as well as customer information from customer relationship management (CRM) and rating agencies, and also open sources of information such as social media. It issues alerts if suppliers pose an increased risk and also suggests new suppliers



SCM: supply chain management VC: value chain QCD: quality, cost, delivery F: finance

1 Supply chain coordination service

and offers matching advice. Hitachi also helps to expand business opportunities for its customers by offering digital solutions and consultation on how to improve assessments. This support draws on the business know-how it has built up in its own manufacturing operations and collaborative creation (co-creation) work.

Through co-creation, Hitachi intends to build supply chain platforms like this that are flexible and community-based.

2 Development of Solution for More Efficient Operation and Maintenance of Cold Storage

Lower operating costs and more efficient maintenance are among the needs of cold storage businesses that operate large, refrigerated warehouses and associated equipment. In response, Hitachi Global Life Solutions, Inc. and Industrial Manufacturing Solution Division of Hitachi, Ltd. have jointly developed a support system and service for maintenance rationalization and the efficient operation of refrigeration. This assists businesses by analyzing a combination of sound, image, and other data on the operation of their refrigeration equipment collected by remote monitoring systems.

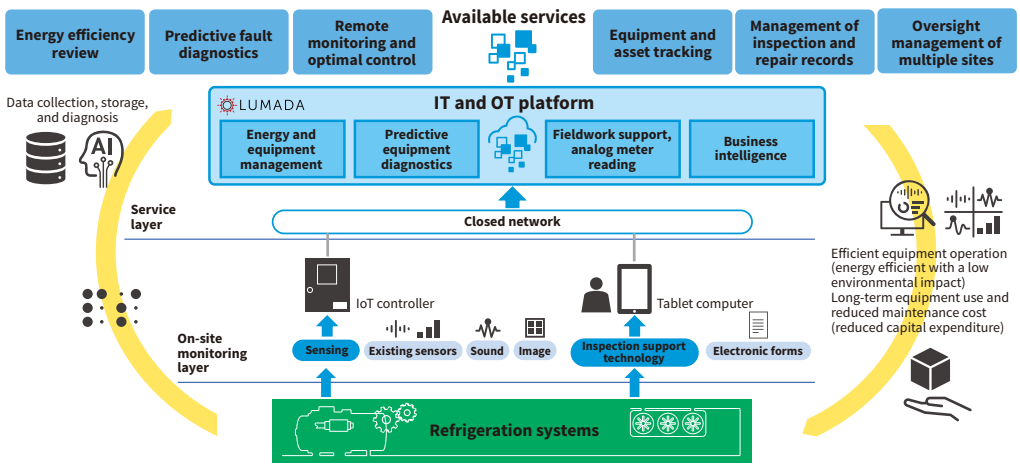
By collecting and analyzing a wide variety of operational data from refrigeration systems, including through interoperation with other systems such as one that uses image processing for automatic analog meter reading, the solution can help achieve more efficient operation and predictive fault diagnostics. For operational efficiency, the solution can avoid unnecessary power consumption by estimating the load on refrigerated warehouses and providing optimal control of parameters such as cooling water temperature and freezer refrigeration capacity. For maintenance efficiency, the solution can interoperate with a service for the remote monitoring and predictive diagnosis of refrigeration equipment to facilitate efficient maintenance planning, providing early detection of anomalies right across the refrigeration system.

The solution will be rolled out progressively as the effectiveness of the various technologies are confirmed.

3 System Control Technique for Symbiotic Safety where People Share Space with Autonomous Machines

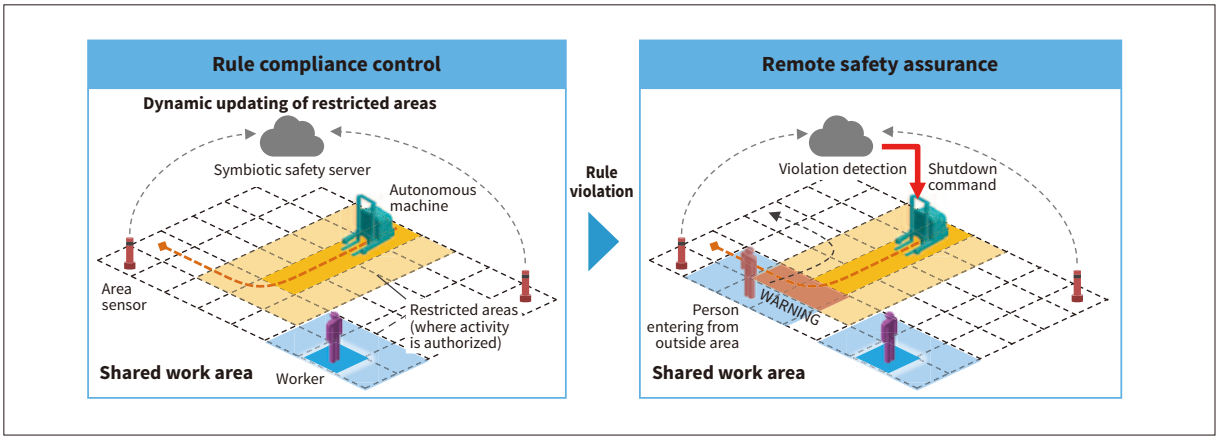
The dilemma posed by the need for safety and work efficiency improvement becomes a challenge when autonomous machines are deployed in environments that are also used by people. To overcome this, Hitachi has proposed the concept of "symbiotic safety" for achieving both safety and efficiency, and has developed system control techniques for putting it into practice.

Symbiotic safety provides functions for balancing safety and work efficiency, with external monitoring of what is happening in the area being kept safe and the ability to operate even when the systems concerned are of different types that have no mutual basis of understanding or communication (such as people and autonomous machines). The main functions are rule compliance control and remote safety protection. These use safety rules as a basis for controlling restricted areas for the equipment being controlled. On detecting a deviation from the rules in the relevant area, restrictions are placed on the actions



AI: artificial intelligence OT: operational technology IoT: Internet of Things

2 Block diagram of support system and service for maintenance rationalization and efficient operation of refrigeration



3 Key functions for achieving symbiotic safety

of this equipment. In a simulation of symbiotic safety involving workers in a warehouse working alongside automated vehicles, the new approach improved work efficiency compared to the past safety control practice of reducing vehicle speed, without compromising safety.

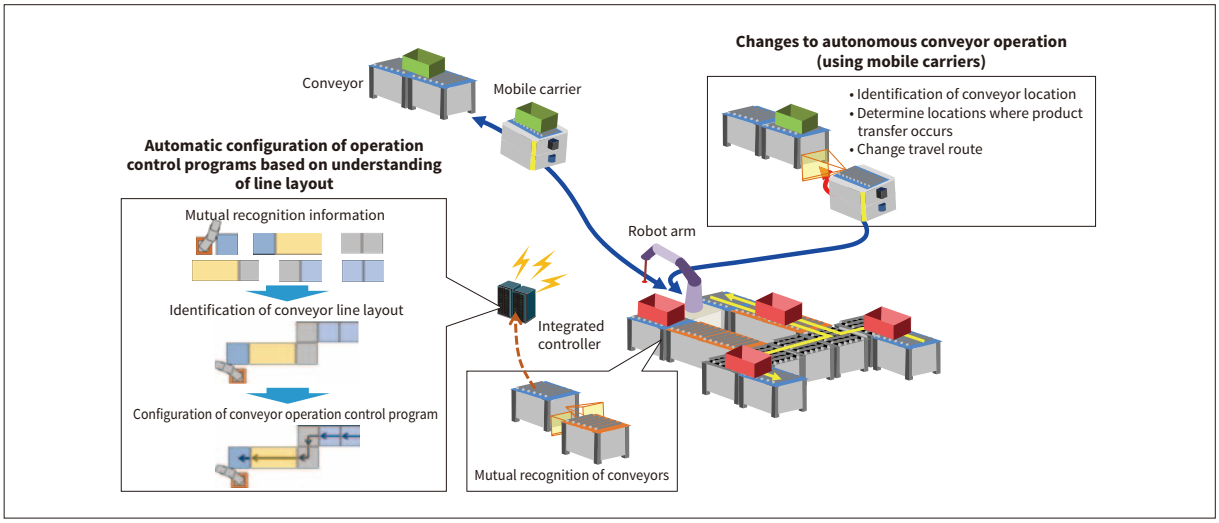
In the future, Hitachi plans to promote the wider adoption of autonomous machines by utilizing this new approach in safety protection functions for a wide range of different applications.

4 System Control Technique for Faster Line Reconfiguration in Warehouses and Other Facilities

To reduce the amount of on-site work needed to set up or reconfigure an item sorting line in a warehouse or other such facility, Hitachi has developed a system control technique that enables conveyors, mobile carriers, robot arms, and other materials handling equipment to identify each other's location and identity (ID), using this to eliminate the need to coordinate the precise positioning of each item of equipment and to automate configuration of their operation control programs.

By providing this equipment with the ability to adjust its own operation based on the location of other machinery, which is determined using the cameras or other sensors mounted on each machine, the system enables the reliable transfer of items from one machine to another. Moreover, the integrated controller responsible for supervisory control of the line is able to determine the overall line layout from the information that connected conveyor machines acquire about each other and configure their respective operation control programs accordingly. When the performance of the system was evaluated using a three-dimensional physical simulation of an automated sorting line at a logistics center, the results indicated that it could shorten the four days of on-site work that were previously needed to reconfigure a line down to less than one day.

With a view to early commercialization, Hitachi plans to assess the performance of this new technique when used on an actual conveyor line.



4 System control technique based on mutual recognition of materials handling equipment

5 Wearable AI for Workload Assessment

5 Work jacket type sensor

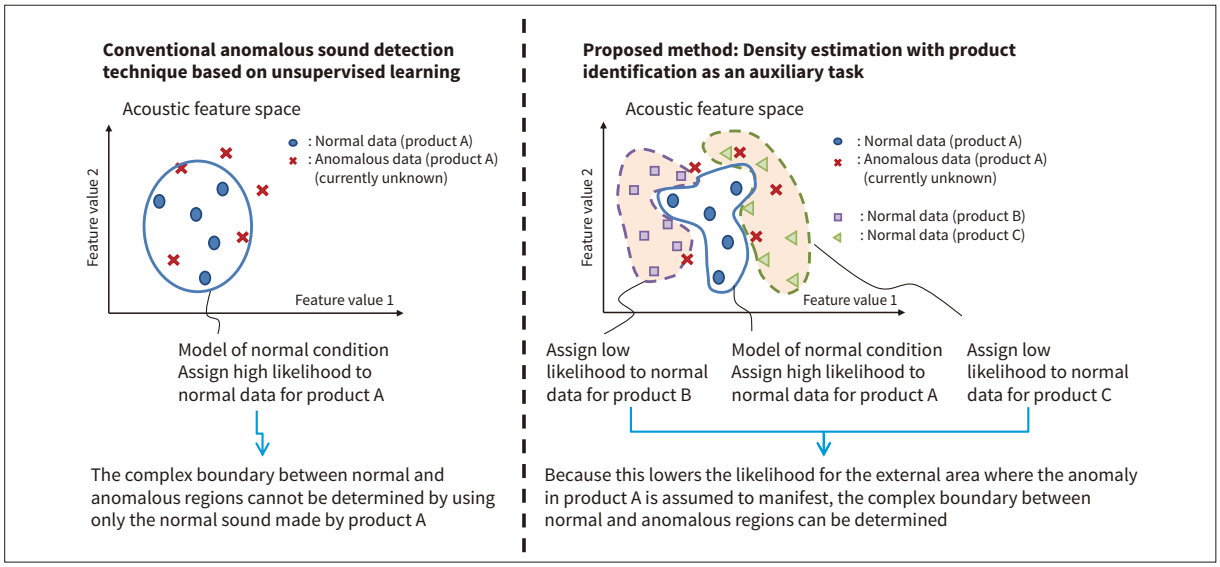
With the aim of offering solutions for improving workplace safety, Hitachi has worked in partnership with DFKI (German Research Center for Artificial Intelligence), its spinoff company sci-track GmbH, and the smart apparel company Xenoma, Inc. to develop a wearable AI that can be used for continuous monitoring of physical workloads.

As measuring physical workloads requires sensors to be attached to a worker, psychological resistance and the trouble involved in attaching sensors present difficulties. By inferring information about the wearer's posture from sensors incorporated into their routinely worn work jackets, on the other hand, the AI system can perform workload measurements that do not cause stress to the wearer. One problem is that, as the sensor is not directly attached to the worker's body, the flexing of the fabric during use becomes a form of noise. However, the AI system compensates for this error by learning how the sensor position changes in response to postural actions. Testing to assess the reliability of posture information obtained this way found an 80.1% accuracy for estimated joint angle, which is sufficiently precise for its use to measure workload.

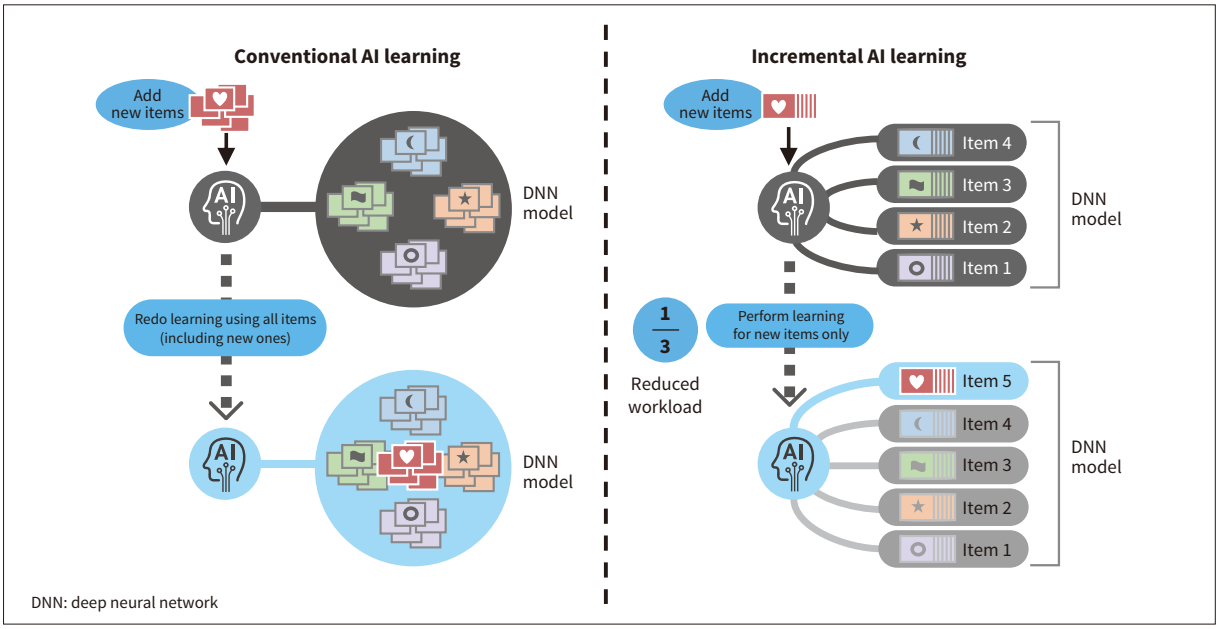
In the future, Hitachi plans to verify its suitability for use in factories, maintenance, and logistics workplaces, recognizing that, by taking advantage of its ability to be worn by workers without stress, the technique can help to improve worker safety and motivation in a wide range of fields through continuous ongoing activity monitoring.

6 AI Technique for Anomalous Sound Detection Suitable for Use in Solutions that Improve Equipment Maintenance and Product Inspection

Hitachi has developed an anomalous sound detection AI for use in solutions that use this to achieve more efficient equipment maintenance and product inspection. While anomalous sound detection requires unsupervised learning using samples of normal sounds only, past techniques have found it difficult to determine the complex boundary between normal and anomalous regions. In response, Hitachi has developed a density estimation technique that treats product identification as an auxiliary task and can determine this complex boundary despite unsupervised learning. Moreover, while past neural networks have had poor accuracy for detecting anomalies in sounds consisting of short bursts, Hitachi has also developed a detection technique based on an interpolation deep neural network that can cope with such sounds. Technical papers describing these two techniques have been selected for the IEEE International Conference on



6 Density estimation with type classification as an auxiliary task



7 Comparison of conventional and incremental AI learning

Acoustics, Speech, and Signal Processing (ICASSP), one of the leading conferences in this field[*1, *2].

Hitachi plans to develop these AI techniques further as it seeks to expand its business in anomalous sound detection solutions.

*1 K. Dohi, T. Endo, H. Purohit, R. Tanabe, and Y. Kawaguchi, "Flow-based self-supervised density estimation for anomalous sound detection," in Proceedings of IEEE ICASSP, 2021, pp. 336–340.
*2 K. Suefusa, T. Nishida, H. Purohit, R. Tanabe, T. Endo, and Y. Kawaguchi, "Anomalous sound detection based on interpolation deep neural network," in Proceedings of IEEE ICASSP, 2020, pp. 271–275.

7 AI Leaning Technique for Easier Registration of New Items to Encourage Use of Picking Robots

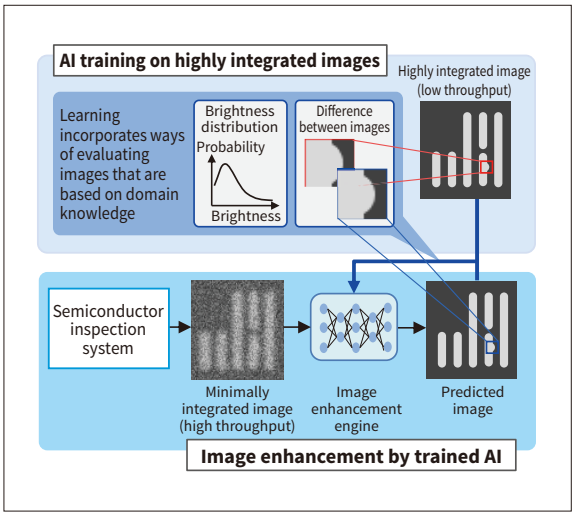
Growth in electronic commerce (e-commerce), the pandemic, and worker shortages are among the factors driving demand for the automation of picking at warehouses and factories. While the use of AI enables the picking of a wide variety of items, one of the challenges with past AI learning practices has been the time and effort required for training and verification. This is because, when new items are added, these techniques have required learning to be performed all over again, including for the data for which learning has already been performed.

In response, Hitachi has developed a learning technique for the AI used in picking robots that can add new items with one-third or less of the work required in the past. This resolves the problem described above by using a new incremental AI learning method that only needs to be trained on newly added items. In the future, Hitachi plans to combine this AI with other autonomous and cooperative technologies to automate logistics operations in ways that combine flexibility and efficiency.

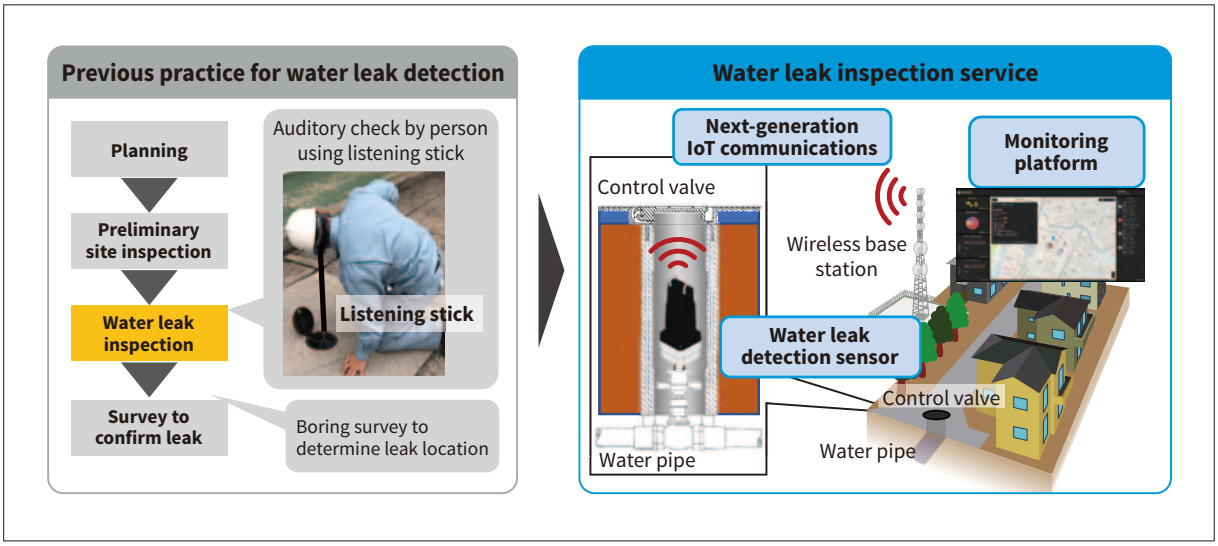
Note that some of the technology described here was the result of work commissioned by the New Energy and Industrial Technology Development Organization (NEDO) (JPNP16007).

8 AI-equipped High-throughput Semiconductor Inspection Solution

As digital devices have grown increasingly sophisticated over recent years and semiconductor production volumes have risen in response to the increasing amounts of data being processed, the scanning electron microscopes



8 Use of AI for image enhancement



9 Overview of water leak detection service

(SEMs) used for semiconductor inspection are expected to provide not only inspection accuracy, but also high throughput. Having studied image processing techniques for the integration of large numbers of images from a semiconductor inspection SEM, this has led Hitachi to develop an AI-based image enhancement technique that can cope with the reduced number of images that can be acquired when throughput is high.

One problem is that, when an AI is trained to eliminate imaging noise so as to replicate the level of noise reduction that is possible when integrating large numbers of images, it also tends to eliminate shape information about the semiconductor circuit with a negative effect on inspection accuracy. However, it is known that the brightness distribution of SEM images follows a probability distribution that is a function of the physical processes in the SEM and the shape of the circuit being imaged. By assessing the differences between predicted images and highly integrated images on the basis of this domain knowledge, an AI learning technique was developed that can capture the shape of semiconductor circuits while also reducing noise. This new technique has achieved high throughput, being able to generate predicted images that offer the same inspection accuracy using only one-eighth as many images as before.

9 Water Leak Detection Service for Reforming Operation and Maintenance of Social Infrastructure

Along with the deterioration of social infrastructure installed during the period of rapid growth, society is also faced with the quality of maintenance work being compromised by workforce shortages and the aging of qualified staff. In the case of water pipes, past practice has been for staff to conduct on-site maintenance inspections using listening sticks, making this an area where efficiency needs to be improved.

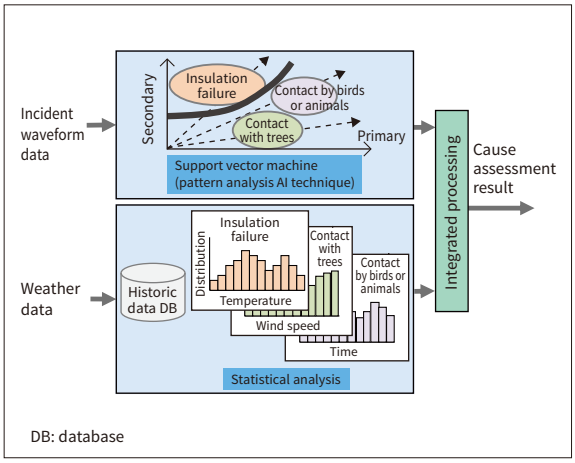
In response, Hitachi has developed a water leak detection service that applies digitalization to the task of water pipe maintenance to make detection more efficient. Combining sensors and the cloud, the service features a proprietary algorithm for detecting even very small leaks and is intended to help reduce the cost of on-site inspections, using a highly sensitive battery-powered vibration sensor for remote monitoring to acquire digital information on the condition of water pipes.

Following practical implementation and testing conducted through joint research with Kumamoto City Waterworks and Sewerage Bureau in FY2020, the service commenced commercial operation in FY2021.

In the future, Hitachi plans to continue with the technical development and practical implementation of the service to help bring innovation to the management of water distribution systems with a view to future social infrastructure maintenance.

10 Cause Assessment Technique for Shortening Outage Duration in Electricity Distribution Systems

The causes of outages on electricity distribution systems can include the failure of insulators or problems caused by trees, birds, or other animals coming into contact with the power lines. While past practice has been for staff to use techniques such as visual inspection to identify the



10 Cause assessment technique for shortening outage duration in electricity distribution systems

cause of an outage, such investigations are often very time consuming. For Kansai Transmission and Distribution, Inc., which is faced with aging equipment and declining numbers of experienced staff, how to shorten the duration of outages caused by distribution network problems is becoming a challenge.

Responding to this challenge, Hitachi has worked with Kansai Transmission and Distribution on a cause assessment technique that can automatically determine the cause of outages, shortening their duration and the time taken for investigation. The technique utilizes the fact that the current and voltage waveforms during distribution system faults differ depending on what caused them. It can quickly and accurately identify the cause of an outage by classifying it using an AI technique for pattern analysis, combining this with statistical analysis of historic system fault and weather data.

The new technique is undergoing field testing to assess its performance. When deployed in practice, it will help to improve the resilience of electricity systems and reduce operating costs.

11 Full-scale Rollout of Online Fault Diagnostics for Connected Home Appliances

Hitachi has developed a fault diagnosis system using online data for connected home appliances that are permanently connected to the Internet.

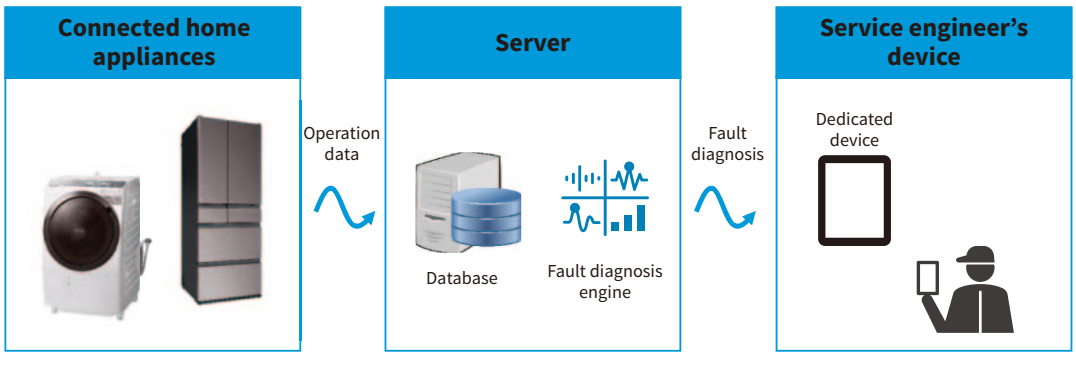
Product problems such as washer-dryers not drying laundry properly or refrigerators with poor cooling performance are difficult for even experienced staff to diagnose because they tend to be intermittent and difficult to replicate. To improve the work efficiency of service engineers, Hitachi has developed a system that can identify the causes of such problems by analyzing operational data stored on an Internet server.

The ability of the system to perform an online diagnosis for problems that would otherwise be difficult to assess can help make service work more efficient, for example by enabling replacement parts to be arranged prior to visiting the user's home and by reducing the frequency of such visits.

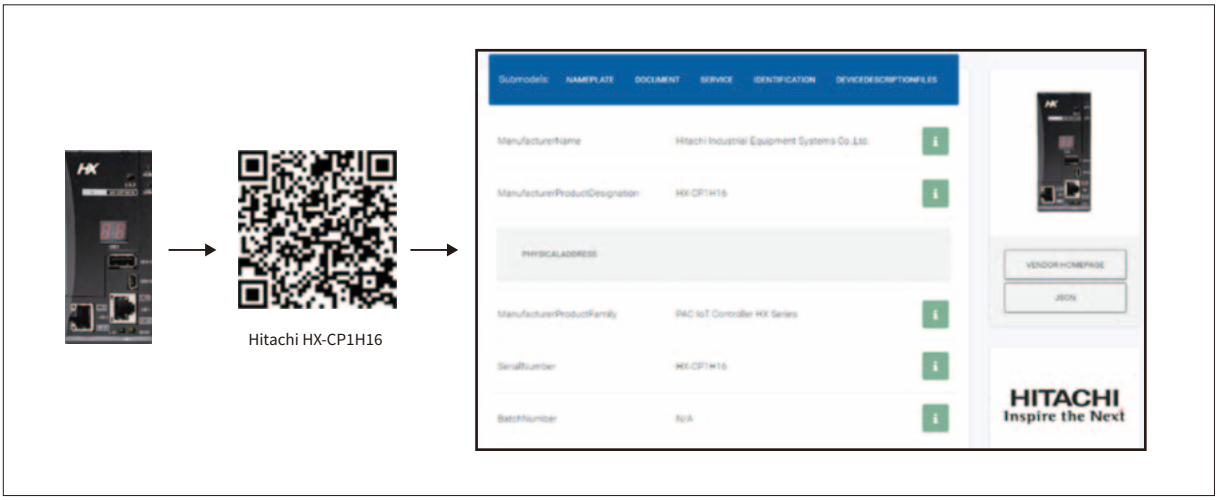
The service has been launched as a tool for engineers throughout Japan who service Hitachi home appliances.

12 Industry 4.0 Digital Nameplate Prototype Released

Hitachi Europe GmbH became members of the German Plattform Industrie 4.0 in June 2016[*1]. This was thanks to a fruitful relationship between Germany and Japan, which resulted in a joint memorandum of understanding. In recent years, Hitachi has participated in several working groups of Plattform Industrie 4.0 and related consortia. Hitachi is also a member of the German Academy of Science and Engineering (ACATECH), which was the innovator of Plattform Industrie 4.0. Hitachi's activity led to a series of publications and projects.



11 Overview of fault diagnosis system



12 Demo sample for a Hitachi HX-CP1H16*3

In this context, Hitachi currently supports the development of the Industrie 4.0 Asset Administration Shell (AAS) concept. For this reason, Hitachi provided a sample AAS of a Hitachi HX-CP1H16 programmable logic controller (PLC) for the digital nameplate demonstration of the German Electrical and Electronic Manufacturers' Association (ZVEI) and Helmut Schmidt University.

The demo shows how a customer could access detailed product information by scanning the attached QR code on the product with their smartphone. All information about the respective product is stored digitally in the AAS*2. Customers can easily access related manuals, configuration files, product certificates and easily access Hitachi's customer support. The customer has a single source of truth (SSOT) and Hitachi can provide the latest product information.

(Hitachi Europe GmbH)

*1 B. Zypries, H. Seko, and S. Takaichi, "Hannover Declaration," the Federal Ministry for Economic Affairs and Energy (BMWi) and he Ministry of Economy, Trade and Industry (METI) Eds. (2016), https://www.plattform-i40.de/IP/Redaktion/EN/Downloads/Publikation/hannover-declaration.pdf?__blob=publicationFile&v=4

*2 BMWi, "Specification: Details of the Asset Administration Shell—Part 1—The exchange of information between partners in the value chain of Industrie 4.0 (Version 3.0 RC01)" (2020), https://www.plattform-i40.de/IP/Redaktion/DE/Downloads/Publikation/Details_of_the_Asset_Administration_Shell_Part1_V3.pdf?__blob=publicationFile&v=5

*3 http://hitachi.i40-aas.de/18?sm=nameplate&sn=HXCP1H16