Technology Innovation: Industry

1 Quality Chain Management

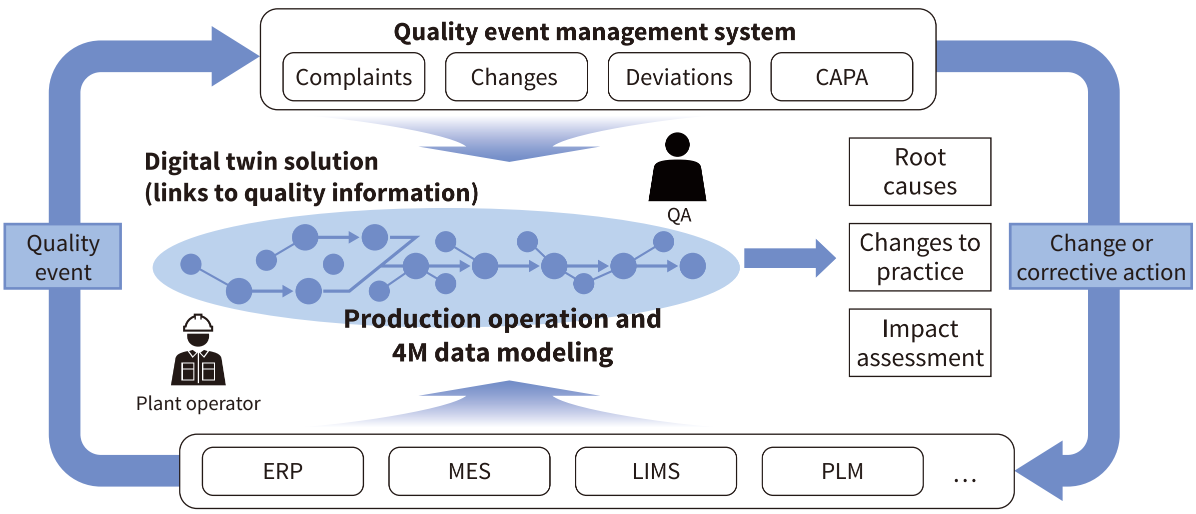
Regulatory compliance and ever stricter quality requirements are among the reasons why the pharmaceutical and medical device industries require a high level of quality management and assurance practices. Unfortunately, the physically separate locations of data such as manufacturing records and quality information mean that collecting information requires a huge number of manhours, one of the consequences of which is a reliance on the expertise of individuals in tasks such as identifying the causes of problems and the impacts of changes. This in turn impedes the sharing of skills and know-how.

To address this issue, Hitachi has developed quality chain management (QCM) as a way to achieve continuous quality improvement through centralized management that links together the quality information scattered across different systems, thereby making quality information from manufacturing both traceable and visualizable. By linking deviance data and product specification changes that occur in the manufacturing process, and user complaint data to the production operation data and man-machine-material-method (4M) data that comprise the data model in Hitachi's digital twin solution, this provides an efficient way to search for the data that indicate the root causes of product quality problems while also presenting a broad overview of the manufacturing process. Through interoperation with Hitachi's digital twin solution, the use of QCM also has the potential to be extended to supply chain management (SCM) and engineering chain management (ECM).

2 Remote Work Support Solution Using 5G

Hitachi is developing a solution for supporting maintenance, inspection, manufacturing, and assembly work in industry, a use case for 5th-generation (5G) telecommunications.

As the number of workers and experienced staff shrink as a result of an aging population and low birthrate, there is a rising need for greater work efficiency



CAPA: corrective action and preventive action QA: quality assurance ERP: enterprise resource planning MES: manufacturing execution system
LIMS: laboratory information management system PLM: product lifecycle management

1 Quality Chain Management

2 Prototype display for remotely located experienced workers

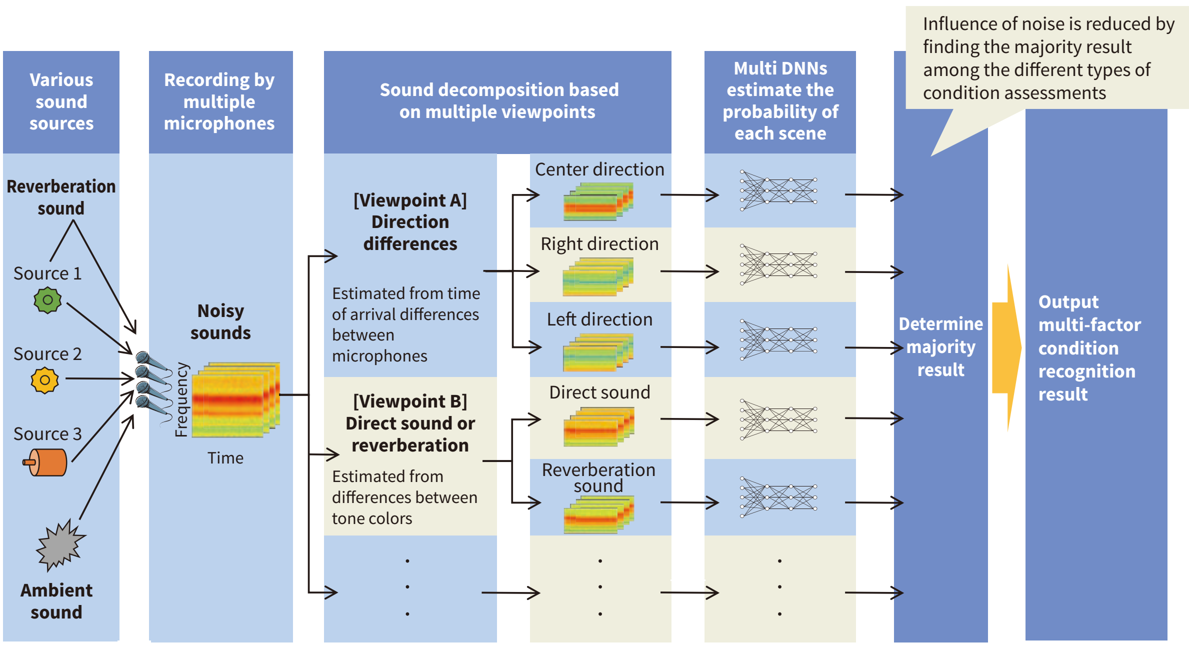
and for shortening the time it takes for inexperienced staff such as young or foreign workers to become useful. In response, Hitachi has come up with a solution for supporting work remotely whereby experienced staff located elsewhere can provide assistance to the inexperienced staff at a site, taking advantage of the high capacity and low latency of 5G to provide them with a high-definition 360° view of the workplace in real time. This helps the experienced staff provide accurate instructions to on-site workers by giving them a detailed view of what is happening from their preferred viewpoint. It also utilizes Hitachi technology for sensing and video analysis to acquire more useful on-site information, including distances, vibration, and sound and also the vital signs and movements of workers.

Through this solution, Hitachi is helping to overcoming the challenge of workforce shortages by providing remote assistance with difficult tasks in a way that conveys a greater sense of presence to remote users in its presentation of information about equipment, conditions, and people at multiple sites.

3 Machine Operating Sound Recognition for Automated Machine-condition Diagnosis

While past practice for the inspection of production machines typically involved experts listening to their sounds and diagnosing their condition, the shrinking workforce has led to growing demand for the automation of such inspections. However, in environments surrounded by various machines such as factories, various types of noise such as ambient sounds and reverberation sounds are mixed, making it difficult to accurately recognize machine conditions.

In response, Hitachi has developed an artificial intelligence (AI) technology that can recognize the sounds made by machines without being affected by noise. This technology decomposes the sounds, which include these ambient sounds, reverberation sounds, and other incidental sounds, from various viewpoints, such as based on the directions or tone colors of the different



DNN: deep neural network

3 Scene recognition using sound decomposition based on multiple viewpoints and overall decision based on multiple DNNs sound sources. The decomposed sounds are then used for the highly accurate recognition of machine conditions. The effectiveness of the technology was acknowledged by its gaining the F1-score*1 on Task 5*2 of the Detection and Classification of Acoustic Scenes and Events (DCASE) 2018 Challenge, the largest international competition in this field.

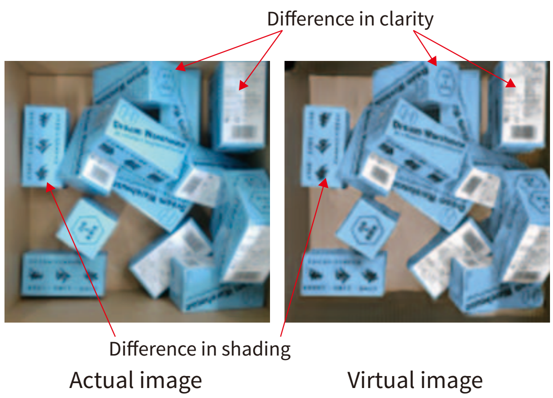
In the future, Hitachi will advance development such as by improving functions and aim for practical application of this technology.

*1 F1-score on Evaluation set (Unknown microphone) is the official evaluation score.
*2 Task 5 is the task in which a system recognizes the scene in which each sound was recorded by multiple microphones in a domestic environment. Each scene is one of 9 categories.

4 Simulation-based Learning Technique Aimed at Object Recognition for Robots

Warehouses or factories are being called on to respond with flexibility to rapidly changing customer needs while also facing labor shortages. While there is potential for using robots capable of a wide range of tasks, these require pre-teaching of a large number of different operating sequences and object images, something that takes a lot of time.

In response, Hitachi has developed techniques that significantly reduce the amount of teaching required by using a large number of virtual operating sequences and object images generated by a simulator for learning, and also by learning how to combine multiple operating sequences needed to perform a required task*1. The work also includes a technique for the accurate and rapid performance of operations based on the learning results*2.



4 Differences in texture of actual and virtual images

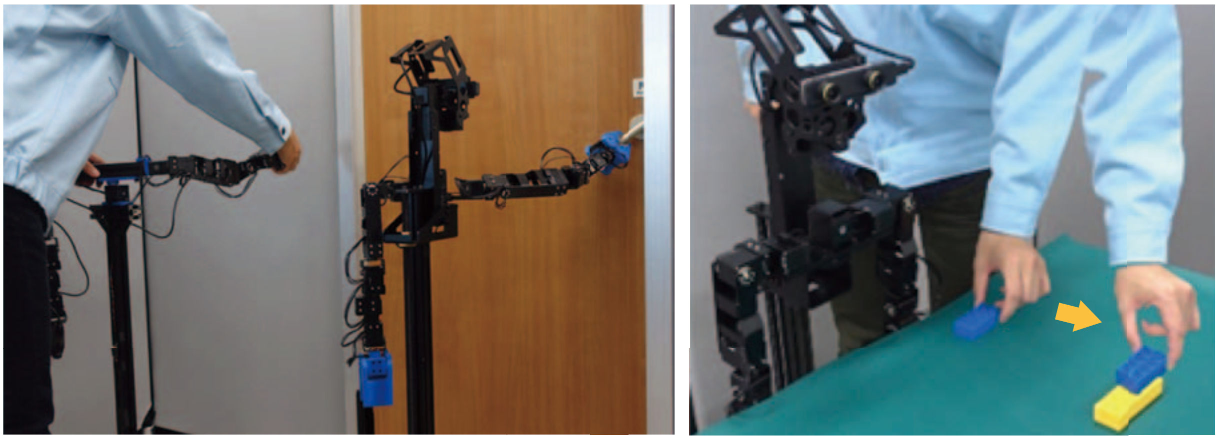
From this work, Hitachi has also gone on to develop a way of dealing with the differences in things like image shading or clarity that arise between the images taken in the real world and the virtual images produced by the simulator. This involves a pre-processing step in the recognition process that uses deep learning to make the real-world images more like the virtual images. By deliberately making the real-world images less real, learning using virtual images is able to work as intended. In testing, the time taken for teaching was shortened by a factor of 80 (24 minutes) without loss of recognition accuracy.

*1 See "Deep Learning Robotics that Uses Imitation to Learn New Operations by Watching a Person's Operations" in the "Technology Innovation – Industry" section (p. 123)
*2 See "Edge AI for Improving Productivity of Autonomous Working Robot" in the "Technology Innovation – Industry" section (p. 126)

5 Deep Learning Robotics that Uses Imitation to Learn New Operations by Watching a Person's Operations

With high hopes being placed on the use of work support robots to overcome labor shortages, Hitachi has developed a deep learning technique that can eliminate the large amount of programming that would otherwise pose an obstacle to their use. Hitachi has previously developed a technique whereby robots can autonomously combine a number of individual operations that they have already been taught. This was successfully used to equip a robot with the ability to open and pass through a door, as a test task, in a single day. However, adding new operations still required a person to operate the robot by remote control and have it repeat the operation many times. To get around this limitation, Hitachi has now developed a technique whereby the robot is able to imitate an action simply by watching a person perform it one time.

The new technique is used during the learning of individual operations, which is conducted as before, and works by extracting values called parametric biases (PBs) that serve as operation indices specific to each operation. By obtaining the PBs for handling an object from camera images of a person performing this action, the technique is able to generate an operation that replicates the action. To test the technique, an actual robot was used to learn the PBs for separate operations that involved moving an object (a block) in circular



5 Teaching in progress using previous remote control method (left) and new imitation method (right)

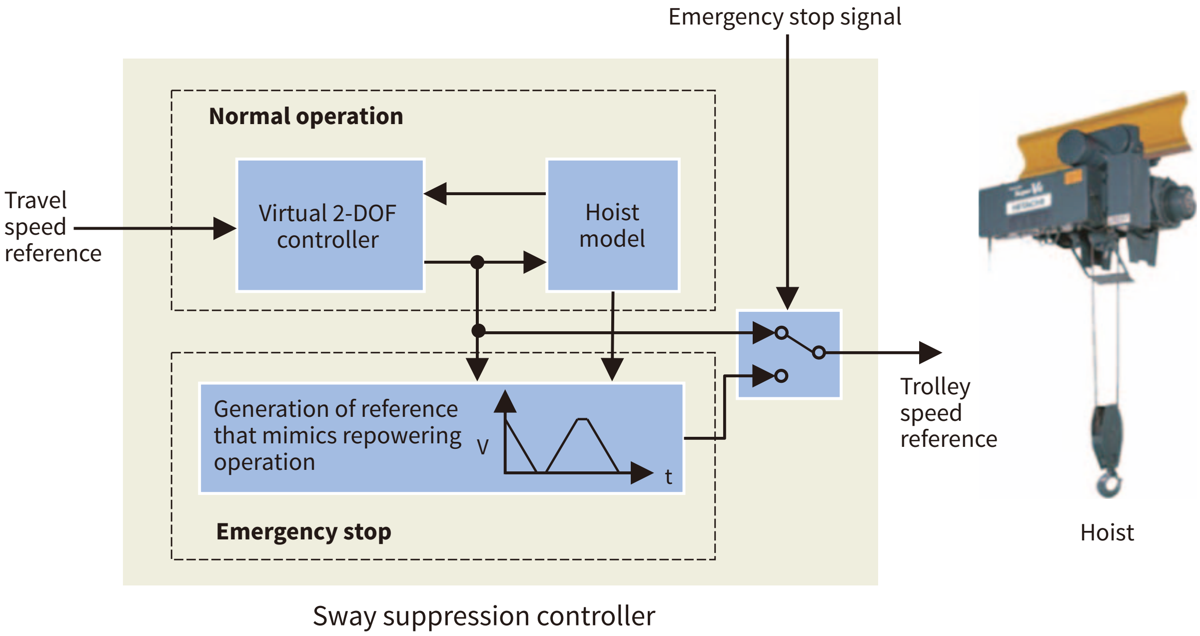
or linear motion. New operations mixing circular and linear motion were then acted out by a person in view of the robot and the PBs estimated, demonstrating that an operation that replicates a particular action can be generated by specifying its PB.

The new technique has a wide range of potential applications in areas like machining and assembly and Hitachi intends to continue to develop features such as reliability and functionality with the objective of future commercialization.

Note that the work described in this article was undertaken as joint research with Professor Tetsuya Ogata's Laboratory at Waseda University.

6 Hoist Control

The aging of skilled workers and rising demand for cranes are creating a labor shortage, a consequence of which is an increasing number of unskilled workers who are unfamiliar with how to operate these machines. Not knowing how to prevent load sway when operating cranes, these unskilled workers are at high risk of collision, catch, and other such accidents. In response, Hitachi has developed a sway suppression control technology that automatically reduces load sway with the aim of supplying hoists that operators can use quickly and with greater safety regardless of their level of skill.



DOF: degrees of freedom

6 Sway suppression controller of hoist

During normal operation, sway suppression control reduces sway by a factor of four or more without using a sway detection sensor by a virtual two-degree-of-freedom control using a hoist model. Furthermore, because changes in wire rope length are input to the hoist model and controller, sway suppression control also works when loads are being hoisted up or down. When a hazard is detected and the crane needs to undergo an emergency stop, the crane follows a deceleration and a trapezoidal wave pattern in a way that mimics a repowering operation that a skilled worker would use to minimize load sway, using the crane's trapezoidal wave drive to cancel out the swaying that the deceleration itself would otherwise cause. By doing so, the crane is able to come to a halt more quickly than it would during normal operation under sway suppression control, while still keeping load sway to a minimum.

In the future, Hitachi intends to continue working on the development of more advanced control technology for greater safety.

7 Functional Enhancements for Hitachi AI Technology/MLCP Plan Optimization Service

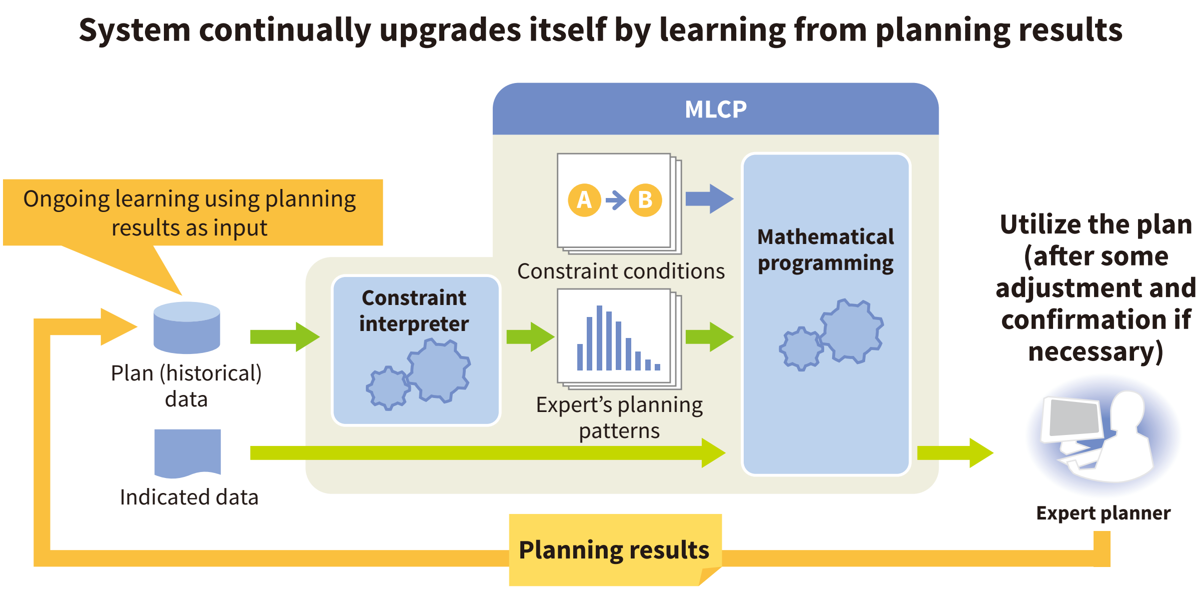
The mathematical optimization technique traditionally used for planning tasks such as production or manpower scheduling are unable to replicate the constraint relaxation and other such tricks employed by experts. To address this problem, Hitachi has developed the Hitachi AI Technology/Machine Learning Constraint Programming (AT/MLCP) technique that combines AI with mathematical optimization. AT/MLCP is able to replicate planning by an expert by applying machine learning to records of plans prepared by experts to quantify the tricks (tacit knowledge) they employ in the form of constraint relaxation values.

Use of the technique to quantify and visualize the plans auto-generated by automatic planning systems can improve these systems by overcoming the lack of clarity that in the past has surrounded the criteria for what is good or bad about plans, and then using this to provide feedback.

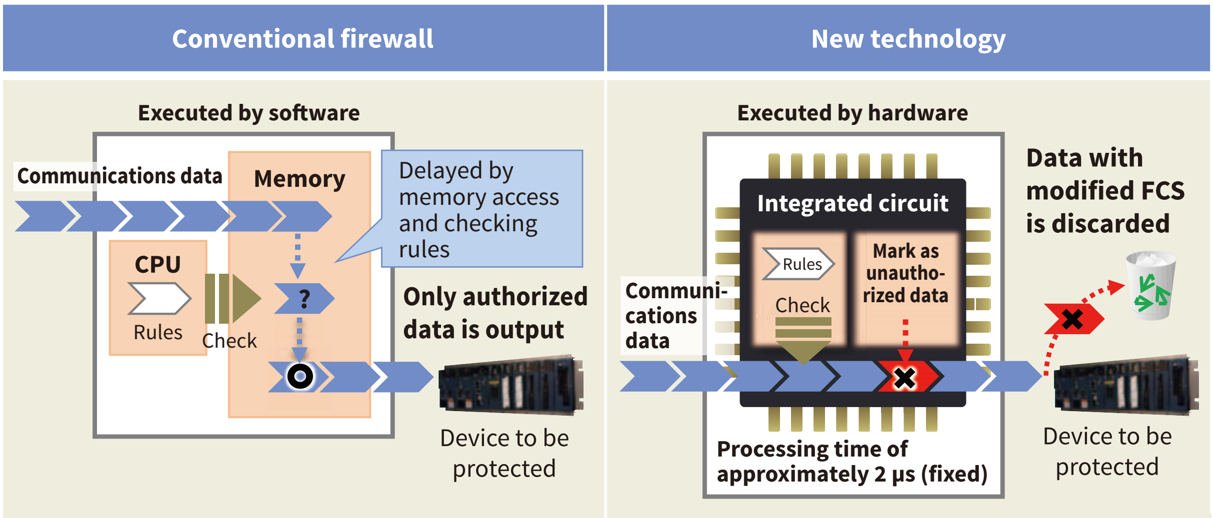
In the future, Hitachi intends to make further enhancements to enable systems to grow automatically.

8 Security Enhancement Technology that Guarantees Real-time Performance of Control Systems

Cybersecurity countermeasures are becoming very significant as the Internet of Things (IoT) spreads and industrial equipment is connected to the network for sharing data. Firewalls intended for use with IT equipment work by temporarily storing communications data in memory and using software running on the central processing unit (CPU) to perform checking. This results in significant communication delays and makes



7 AT/MLCP combining mathematical optimization with AI



8 Real-time detection of unauthorized communications data (comparison with conventional technology)

the practice unsuitable for industrial equipment where real-time performance is needed (with cycle times that extend down to the millisecond range).

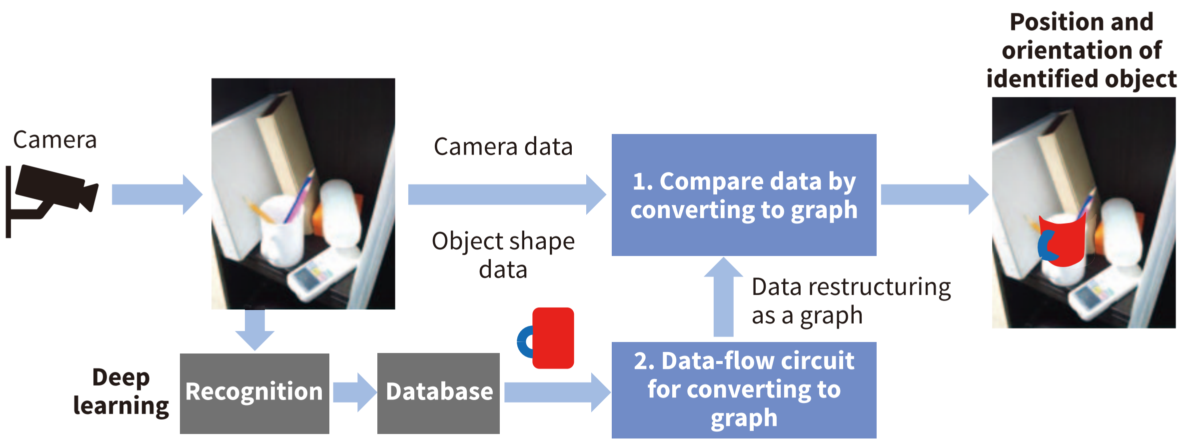
In response, Hitachi has developed a technique that uses a proprietary checking algorithm to distinguish between authorized and unauthorized data without interrupting the flow of communications, with unauthorized data being marked by modifying its frame check sequence (FCS) so that it can be discarded by the host device being protected. When implemented on a field-programmable gate array (FPGA) for testing, the technique took only about 2 μs to check communication data, a time that is sufficiently short compared to typical control cycle times.

In the future, Hitachi intends to undertake further testing of the technique to help improve security in the industrial IoT sector.

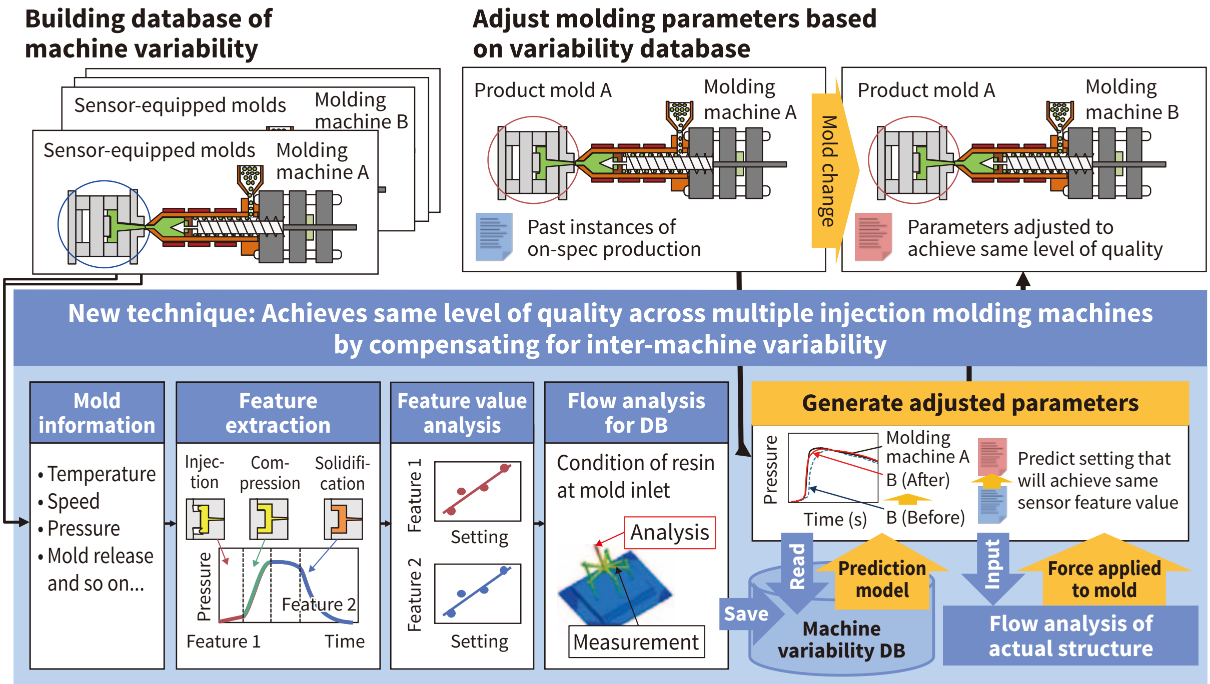
9 Edge AI for Improving Productivity of Autonomous Working Robot

The heavy computational load for AI used in robots makes it important to reduce both the load and power consumption by using efficient algorithms and hardware and implementing them in controllers. To this end, Hitachi has developed a technique for the high-speed comparison of three-dimensional image data obtained from cameras and rangefinders with object shape data, and has combined this with deep learning to enable the real-time recognition of objects with complex shapes made up of flat and curved surfaces.

This works by converting object shape data to a graph, enabling images to be compared against object shapes with high efficiency. A dedicated circuit for the efficient execution of the graph conversion process was also implemented on an FPGA and used as an



9 Efficient technique for recognition of objects with complex shapes



DB: database

10 Overview of system for compensating for variability between different injection molding machines

accelerator. When implemented in a hardware configuration suitable for use in a controller, this was approximately 10 times faster than past methods for comparing images and object shapes. As a result, it took only about 0.6 s to identify the position and orientation of objects arranged randomly on a shelf.

In the future, Hitachi intends to encourage greater automation of warehouses and factories by continuing to pursue this approach to developing techniques that enable various types of robot AI to be implemented in controllers.

10 Compensation Technique for Machine-to-Machine Variability in Injection Molding

Against a background in which a shortage of experienced staff has people looking for ways to avoid dependence on specialist expertise, rapid progress is being made both in Japan and elsewhere on IoT-based innovation in manufacturing processes. For the injection molding process, Hitachi has studied how to optimize molding parameters in ways that take account of the features (distinguishing factors) of injection molding machines that currently rely on operational know-how, using this to develop a technique for adjusting these parameters so as to achieve the same level of quality across multiple machines.

The technique combines flow analysis with visualized data from sensor-equipped molds to determine the condition of the resin at the mold inlets of a number of injection molding machines that have been setup with the same molding parameters. A prediction model for mold condition with respect to molding parameters was then obtained through an analysis of the feature values for resin condition collected by this means. When a mold change occurs during routine production, this prediction model is used to automatically adjust the molding parameters so as to deliver the same level of quality as before the change. In testing, the new technique succeeded in reducing weight variability across a number of machines with the same molding parameter settings from 7.3% to 1.1%, shortening the production lead time and delivering more consistent quality.

In the future, Hitachi intends to conduct further testing of the system using different products and molding machines.

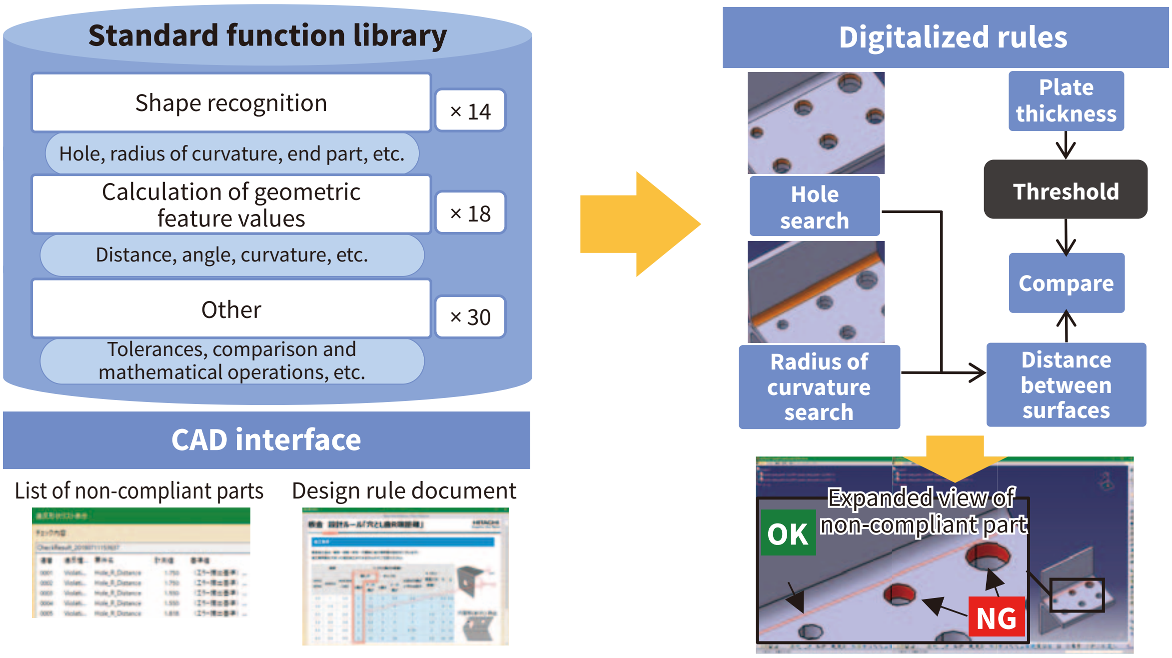
11 Design Insights Support CAD System

Hitachi has developed a design insights support computer-aided design (CAD) system that helps to highlight issues in 3D-CAD by performing automatic design rule checking for things like ease of manufacturing or maintenance.

By facilitating the identification of design rule violations at the design stage, the system can reduce the workload for design rule checking as well as the amount of rework after production and maintenance commence. The system is being made available as one of the services provided by the Hitachi Digital Supply Chain/ Design solution that supports globally collaborative design.

The system includes a standard library made up of shape recognition functions for identifying shapes in the 3D-CAD model that need checking and functions that make dimensional measurements to calculate geometric feature values. Because this combination of functions enables the automation of CAD operation procedures for design rule checking that were performed manually in the past, the system is able to adapt flexibly to a wide variety of design rules that incorporate company-specific know-how.

The system is being deploying for a wide range of products, including in the automotive sector and across the Hitachi Group, and has reduced design lead times for Hitachi products by about 30% due to a lower frequency of rework and the automation of checking work.



11 Diagram of design insights support CAD system