Featured Articles

AI Technology

Achieving General-Purpose AI that Can Learn and Make Decisions for Itself

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OVERVIEW: There are increasing trends toward utilizing the big data collected at companies and the data acquired through the IoT to generate new management value. Of these trends, AI technology is attracting attention as a means of intelligently utilizing large amounts of data by making full use of computer processing capacity. Hitachi is developing Hitachi AI Technology/H, which optimizes and automates decision-making in various ways through the utilization of large amounts of data, thereby contributing to improvements in outcomes for corporations. This article first describes the trends in and types of AI technologies, and then explains the concepts and basic principles of Hitachi AI Technology/H Hitachi has developed. Furthermore, it touches on the technology's potential as a general-purpose AI solution that can shed light on complicated problems through possible applications in a wide range of different industries and fields.

INTRODUCTION

MOVEMENTS are picking up steam in every industry towards the utilization of the large amounts of big data being collected by companies and the new data being gathered through the Internet of Things (IoT) to enable management reforms such as internal operational reforms and the creation of new customer-oriented services. As data volumes increase, however, the requirements of traditional methods based on having humans test hypotheses exceed the limitations of human cognition, making it difficult to utilize data effectively. This makes it necessary to use artificial intelligence (AI) that can automate the extraction of value from large quantities of data by applying intellectual algorithms that can replace humans[(1)]. Expectations are also high for AI that can learn by itself in order to acquire knowledge.

This article describes the concepts and basic principles of Hitachi AI Technology/H[(2)] promoted by Hitachi (hereafter referred to as H), and the possibilities for application in a diverse range of industries and fields.

AI: A NEW WAY TO UTILIZE COMPUTERS

Toward Computers that Can Learn from Data

The general roles played by traditional computers and business applications were to execute predefined functions and automate business processes. In other words, the flow of development traditionally entails designers (humans) envisioning and designing functions in advance, after which programmers code the logic. As the performance of computers continues to increase and prices continue to fall, this is expected to enable more intellectual processes in the future as opposed to the traditional fixed processes. Specifically, the availability of a wide variety of different types of data, including the IoT and other types of sensing, technological advances such as the expansion of feedback targets including wearable devices and humanoid robots, and other factors are working together to help facilitate flexible responses from computers to changes in data, thereby enabling learning from experience (see Fig. 1). When it comes to intellectual computer processing, although intense research efforts have been focused on the field of AI since the 1980s, the type of AI for which humans build in cause and effect rules in advance has not been able to understand the diverse range of user contexts, and thus has not reached the level of practical application. In recent years, however, the availability of inexpensive high-performance computers and high-capacity data storage is triggering a technological upheaval, and expectations are running high for machine-learning AI that can learn from data.

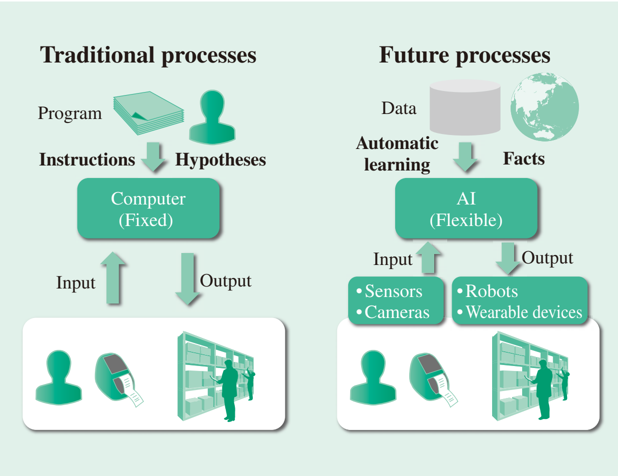

Fig. 1—Computers Transitioning to AI that Learns from Data. Instead of fixed processing that must be designed in advance, this AI enables processing that is more intellectual and flexible.

New AI for Optimization and Decision-making

Table 1 shows the H technology Hitachi is developing and promoting along with other representative types of AI (and intelligent systems), categorized by type. Based on the role it plays, AI can be categorized as either the searching type, which supports humans as an intelligent machine with expert systems and other functions at its core, or as the recognition type, which emulates the ability of humans to recognize images or voice input through seeing and understanding or hearing and understanding.

International Business Machines Corporation's (IBM's) Watson*1 and other AI systems of the searching type take newspapers, technical papers, and other documents and text data as input and use natural language processing technology to search for information and provide responses. As for the recognition type, deep learning and other technologies have been starting to advance at a rapid rate in recent years, toward the achievement of recognition functions based on the effective extraction of patterns from massive amounts of image and voice data. Hitachi's H goes beyond those two categories, however, by achieving automation of optimization and decision-making. More specifically, H is characterized by the ability to automatically generate models for improving specified outcomes based on a wide range of mixed numerical data types.

*1 IBM and Watson are trademarks of International Business Machines Corporation, registered in many jurisdictions worldwide.

Table 1. Positioning of H

The strength of Hitachi's H technology lies in its ability to convert a wide range of mixed numerical input to corporate profit.

Type	Search	Recognition	Optimization and decision-making
Representative example	IBM Watson	Google* Deep Learning	Hitachi H
Data	Documents/ Research papers (Text)	Images/voice (Signal waveforms)	Corporate information/ sensors (Heterogeneous mixed numerical values)
Utilization situations	• Information searching • Physician assist	• Security • Wearable user interfaces	• Creating profit
Destructive technology	Page ranks (1998, L. Page)	Deep learning (2006, G. Hinton)	Leap learning (2014, Hitachi)

IBM: International Business Machines Corporation
* Google is a trademark of Google Inc.

CONCEPTS AND BASIC PRINCIPLES OF H

Automating the Generation of Hypotheses

In addition to technical challenges such as the achievement of raw computing power and storage capacity, the effective utilization of large amounts of data is also accompanied by a redefinition of the roles of both humans and computers. In other words, with the traditional approach of having humans first come up with hypotheses, gather the data that is required, and then attempt to validate the hypotheses, it is difficult to fully utilize the large amounts of frequently updated data. Also, the problems that must be solved for society or for companies are themselves growing more complicated, to the extent that even for experts in the relevant fields, the capacity of humans to recognize methods for constructing sophisticated predictive models is being exceeded. In the future, an effective approach will be to fully utilize data and computers by having humans set the problems to be solved (the outcomes to improve) so that the computers can automatically generate a large number of hypotheses and discover solutions by following the data.

Principles of H

H is an analytical engine that recursively derives from large amounts of data the correct measures and how they should be implemented in order to improve the target indicators that represent value for customers [key performance indicators (KPI), etc.]. Rather than collecting models of detailed work processes, H focuses on modeling outcomes in a data-driven system.

The principles of H are shown in Fig. 2. H uses a numerical table format to input data that might influence outcomes such as management effects to

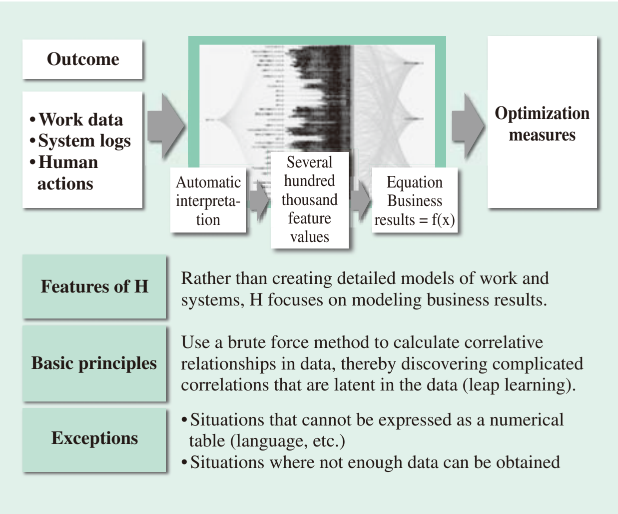

Fig. 2—Principles of H.
Hitachi's proprietary leap learning technology derives the factors required for improving business outcomes from the data.

be increased or decreased (sales, productivity, design bugs, service disengagement, and so on).

H internally generates an exhaustive number of combinations of the input data, generates huge amounts of feature quantities for each combination, and then uses a brute force method to calculate the relationships between these feature quantities and the outcome in order to discover any complicated correlations that are latent in the data through statistical processing. The output of H is an equation that describes the correlation between the outcome and the feature values of the combinations. By taking this equation as an optimization function, and incorporating it into work and control systems in combination with outcome improvement prototype designs and means of providing execution, it is possible to continuously improve outcomes while tracking data even if the environment or orders change.

Also, since it is easy to envision combinatorial explosions occurring if huge numbers of data parameters are input, a variety of different measures are taken to inhibit this problem. One of the techniques that was developed is spatial deformable clustering (SDC), which is an advanced version of grid-based clustering that enables the automatic discovery of regions of data combinations that might strongly affect the outcome (see Fig. 3)[(3)]. By increasing or decreasing phenomena with respect to the regions identified by this technique, it is possible to effectively control the outcome.

AUTOMATION OF SYSTEM OPTIMIZATION AND DECISION-MAKING

Online AI

H is not only utilized for data analysis, but it can also be connected to existing systems and utilized for optimization and decision-making as well (see Fig. 4).

In other words, it regenerates models by adapting to daily changes in the environment and orders, and can maximize management effects by contributing to productivity and reducing costs. Specifically, H enables the implementation of adaptive and self-improving systems by using equations related to the output of outcomes as optimization functions and narrowing down a variety of different complicated work and control systems into mathematical optimization problems. For example, H can be used to automatically track changing on-site conditions in order to improve outcomes in various environments including manufacturing lines, warehouses, and stores.

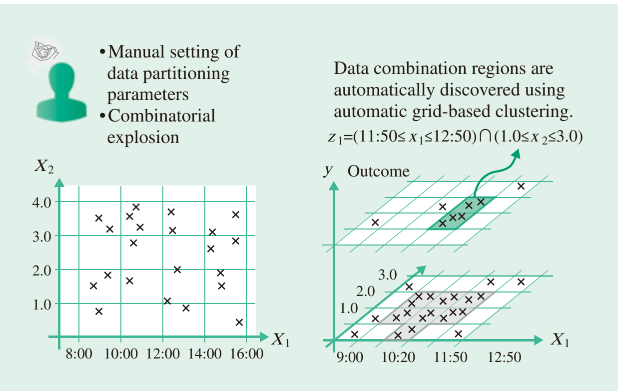

Fig. 3—Spatial Deformable Clustering (SDC).
The grid-based clustering technique is utilized in order to automatically discover data combination regions that might strongly affect the outcome.

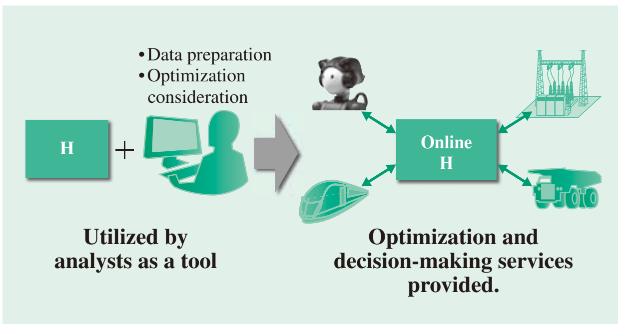

Fig. 4—Online AI Providing Optimization and Decision-Making Services.
H is connected to the system in order to automate optimization and decision-making.

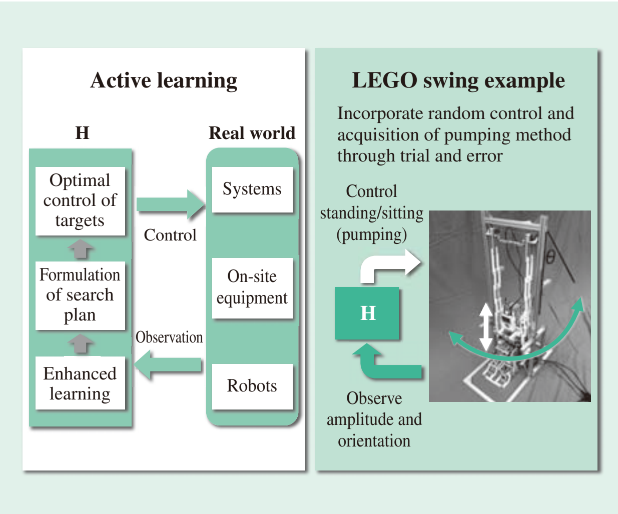

Fig. 5—Active Learning.
H incorporates enhanced learning capabilities in order to enable the automatic learning of optimization parameters.

AI that Learns from Experience

Furthermore, H can not only be applied to past data, it also attempts to actively search for methods that can more optimally achieve objectives by acquiring new data by itself. The example shown in Fig. 5 is a prototype of an experimental system connecting H to a swing robot that was created using the educational LEGO*2 Mindstorms*2 product. This experiment was designed to see whether or not the robot could learn how to swing on a swing without being given a model beforehand.

With the target indicator corresponding to the outcome set as increments in the swing's deflection angle, and with the deflection angle, pumping state, and pumping operation acquired from the system set as explanatory variables, the AI gradually generates a model by maximizing the outcome with random pumping patterns, thereby enabling the robot to successfully swing on the swing after an average of approximately five minutes. Furthermore, the robot was able to increase the outcome (the swing's deflection angle) by using the unexpected method of pumping at both ends of the swing.

Although it is necessary to fully consider possibilities such as a system running amok when implementing enhanced learning AI of this type, it can be used to greatly contribute in areas such as optimizing the parameter control of complicated control systems, or implementing robust systems that handle changing environments.

*2 LEGO and Mindstorms are trademarks of the LEGO Group.

Table 2. Fields where H is Utilized
H is highly versatile because its level of dependence on modeling and tuning based on field-specific domain knowledge is low.

Industry or field	Targets of optimization and decision-making
Production	Control manufacturing equipment parameters
Traffic	Fuel-efficient driving control, maintenance optimization
Distribution	Optimize product placement, warehouses, and task sequences
Marketing	Customer analysis, proposal of recommended products
Office work	Automate approvals, improve happiness

POSSIBILITIES AS A GENERAL-PURPOSE TECHNOLOGY

The effectiveness of H has been confirmed via application in 24 case studies covering seven fields. The core algorithms of H are characterized by independence from modeling or tuning based on domain knowledge in each field. In other words, unlike previous types of AI that had to be specialized for each field, H is versatile enough to automate the optimization and decision-making of a wide range of different systems, so all that is necessary is to specify the outcome to be maximized and to input data that might be associated with changes in that outcome. By taking advantage of this characteristic, H can be applied to a diverse range of problems in society as well as different industries, fields, and sectors. Table 2 shows the fields Hitachi is currently envisioning for the application of H.

CONCLUSIONS

This article discussed the concepts and basic principles of the H optimization and decision-making AI system championed by Hitachi, as well as the possibilities of adding intelligence to existing systems.

Whereas the type of AI that specializes in a specific field by utilizing domain knowledge has traditionally been in the mainstream, H's key characteristic is its high level of versatility. All that is necessary to use H is to specify the outcome to be increased and to input the data that might affect changes in that outcome in order to automate system optimization and decision-making. H can contribute to the solution of a large number of complicated problems in order to improve corporate outcomes, including the control of parameters for manufacturing equipment, the optimization of operation control, the proposal of optimal products to customers, and so on.

In order to strengthen intelligence technology even further, Hitachi will continue working to make it even easier to connect to existing systems, develop new feature quantities, apply predictive diagnostics, construct a service framework to enable application to even more industries, horizontally deploy usage and application logic with the assistance of the open development community, and engage in other efforts to further expand H.

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