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Approaches to Driving Digital Innovation with Information Technologies

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Abstract

Digital innovation with advanced information technology enhances business competitiveness and increases the power of value creation. We, NS Solutions Corporation, Systems Research and Development Center, have been researching various types of digital innovation technologies such as AI, IoT, AR and many others. In this paper, we introduce five researches on digital innovation, the details of which are as follows: 1. How "KAMONOHASHI", the platform for deep learning, improves the productivity of deep learning applications, 2. Company-wide data analysis integration environment "Data Veraci", 3. "Narabikun" as a sequence optimizer for continuous production line scheduling, 4. How the "IoX Platform" works as a foundation of IoT applications, and 5. The latest trends and application examples of AR (augmented reality).

1. Introduction

Information technology (IT) with artificial intelligence (AI) as its center has been advancing at an accelerated pace recently. Digital innovation in which IT is actively used to reform businesses is becoming a major source of business competitiveness and value creation. To achieve digital innovation, technical strength to understand and apply continuously advancing high-level IT and to use it effectively is required. In addition, to apply such IT to business issues that are becoming increasingly complicated, the ability to combine multiple technologies to produce new solutions is required in addition to the ability to use individual technologies.

The Systems Research and Development Center of NS Solutions Corporation (NSSOL) has been engaged in research and development required to produce new solutions for more than 30 years using the advanced IT of each era. This paper briefly introduces the Systems Research and Development Center's activities and its latest efforts to fully exploit advanced IT.

2. Systems Research and Development Center's Activities

The Systems Research and Development Center has been working under the three missions of "research and development", "business support", and "human resource development" with the aim of excelling as an organization that researches, develops, and applies advanced IT and solves technical problems of society, customers, and our own company.

In research and development activities, we have been researching and developing how to use advanced IT practically in enterprise information systems and how to develop, manage, and maintain enterprise information systems in which advanced IT is used. Recently, we have been placing importance on researching and developing technical domains required for the advancement of information systems and systems that assist humans in carrying out intellectual work, represented by clouds, IoT, and AI, which can differentiate us from other companies.

In business support activities, to evolve the research and development outcomes and technical knowledge that we have acquired through such research and development and to put them to practical use, we even engage in actual system development. Recently, to achieve digital innovation, in particular, the Systems Research and Development Center, which has technologies required for such purpose, has been working with customers to co-create new values.

In human resource development activities, we have been developing human resources related to advanced IT in various ways to

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use it more efficiently.

Our research, development, and activities to co-create values in specific advanced IT domains are introduced below.

3. Support for Developing Deep Learning Technologies

3.1 Advancement of deep learning technologies

Deep learning is a variant of AI. It was when an image recognition contest was held in 2012 that deep learning received widespread attention for the first time. In a short period of six years since then, deep learning has been spreading into our daily life with tremendous force. For example, the merchandize most bought on Black Friday in 2017 was Amazon AI speaker Alexa[1]. If you want to have an AI device[2], you can buy an iPhone since iPhones have deep learning chips. AI has become social infrastructure: China has 170 million AI cameras[3] around the nation and the Chinese government is planning to increase the number in the future.

Sectors where deep learning has produced excellent results so far are only the image and audio sectors. However, the AI's levels in two of the five human senses has become equal to those of humans, which is expanding the areas where AI and by extension computers can function well.

3.2 Application of deep learning technologies in industry circles

As it became possible for deep learning to produce excellent results that used to be unexpected, it has been applied in various ways in industry circles where specialists gather. For example, Seagate Technology LLC, a leading hard disk manufacutuer,[4] started using deep learning for pre-shipment product inspection. The company uses deep learning to find and classify fine scratches on disks to identify causes at an early stage or for other purposes. Seagate had been working on using AI for pre-shipment inspection before that and it reported that the appearance of deep learning had enabled high-performance simple inspection.

As more advanced work, Glidewell Dental Lab, a company that manufactures and sells artificial teeth, has been working to use deep learning to design artificial teeth that are suitable for each person. The company reported that deep learning had enabled a large volume of design instantaneously and detailed design on points that humans tended to handle roughly in designing.

3.3 Problems with applying deep learning to industries

A technique called statistical learning that analyzes the trends from past data and that makes estimates based on such trends when new data is added is supporting the current rush of deep learning. A large volume of data given for this statistical learning has succeeded in significantly enhancing the performance. This is deep learning.

The background of deep learning that it analyzes the trends from past data also serves as its weak point. For example, when deep learning tries to inspect completely new products, if they are different from the trends of past products, it cannot make good estimations.

In addition, humans cannot estimate the results of such tasks—analyzing the trend from data—by deep learning well. For example, when three persons are asked "how many rainy days will June have?", their answers will probably differ. Many humans can accurately estimate the behavior of programs in which deep learning is not used. On the other hand, programs using deep learning include estimation of trends, so it needs to consider that their behavior may be different from what humans intended.

Thus, deep learning has a major weak point, but it has spread widely throughout society. You can enjoy deep learning's benefits that more than offset the weak point by understanding its characteristics and considering application targets and application/management procedures in advance.

3.4 Platform for supporting the development of deep learning technologies

To support the application of deep learning technologies in industry circles, NSSOL has developed a platform for supporting the development of deep learning technologies called KAMONOHASHI[*1] (**Fig. 1**).

As mentioned above, a large volume of data supports deep learning technologies. Therefore, KAMONOHASHI provides various

[*1] KAMONOHASHI is a registered trademark of NS Solutions Corporation in Japan.

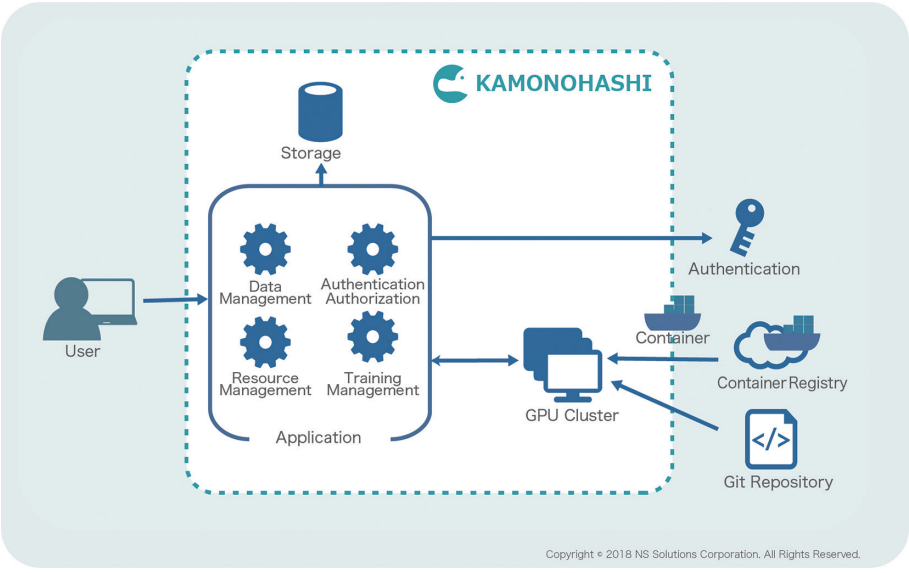

Fig. 1 Overview of KAMONOHASHI

functions for smoothing data management. In KAMONOHASHI, data used to develop deep learning technologies can be managed in the unit of data set. This enables you to understand what pattern of data is being trained. In addition, data obtained in actual operation can be add as validation dataset into KAMONOHASHI. And the accuracy of trained model to the validation dataset can be recorded. This function allows you to understand from what patterns—training dataset and other conditions—accurate results can be obtained and from what pattern the results are not correct. In addition, the function makes it possible to add data that deep learning is not good at and new data patterns for fine-tuning and you can compare the accuracy.

Furthermore, deep learning requires large-scale calculation in addition to a large volume of data processing. KAMONOHASHI provides functions for preparing environments required to develop deep learning and for allowing multiple researchers to share a high-performance computer to develop deep learning in an efficient way.

3.5 For making the most of deep learning

Deep learning has advanced remarkably and has been evolving day by day, still producing new fruits. Using these favorable results can allow you to enjoy new benefits. Meanwhile, weak points of deep learning that were not seen in conventional programs need to be taken into account. To handle issues unique to deep learning, development and application procedures need to be reviewed and platforms supporting deep learning need to be used.

4. Data Analysis and Data Veraci[*2]

4.1 Research and development in data analysis technical domains

Data analysis technologies are used to extract valuable information from data, being essential for making the most of data to improve business operations. Recently, as efforts to make efficient use of data have become active, new data analysis technologies have been devised one after another thanks to the rapid development of the data processing platform. Therefore, surveying and learning the latest technical trends is an important task in the research and development of data analysis technologies. Meanwhile, the original objectives of data analysis are to use data effectively and to improve business operations. Therefore, research domains of data analysis need to cover all processes from the identification of problems with business operations to the application of appropriate analysis techniques to such problems and feeding information back to the business operations in addition to covering technical elements.

4.2 Data analysis platform Data Veraci

When data analysis processes are generally viewed, issues are the provision of processes and environments for promoting data analysis projects efficiently, the life cycle management including management, monitoring, and improvement after data analysis models have been applied to business operations, and the development of human resources related to data analysis. For the problems with the provision of data analysis processes and environments, our outcomes have been turned into the data analysis integration platform Data Veraci. Data Veraci provides a data analysis tool and project management tool to execute analysis processes as a cloud environment (**Fig. 2**).

KAMONOHASHI mentioned above provides a scheme that makes it easier to manage data, models, and results by focusing on deep learning technologies. However, the application purposes of Data Veraci are not limited and thereby Data Veraci is a general-purpose environment in which data analysis can be carried out in various ways.

As the analysis tool, a scheme in which environments to execute general-purpose programming languages provided as OSS (e.g., Python and R) can be used via Web browsers is used. Data analysts used to often use expensive commercial analysis tools. However, recently analysis tools based on OSS have been developed and in which the latest algorithms have been implemented as a package without little delay in some cases. Using such tools efficiently is becoming a skill necessary for data analysts. In addition, in some cases,

[*2] Data Veraci is a registered trademark of NS Solutions Corporation in Japan.

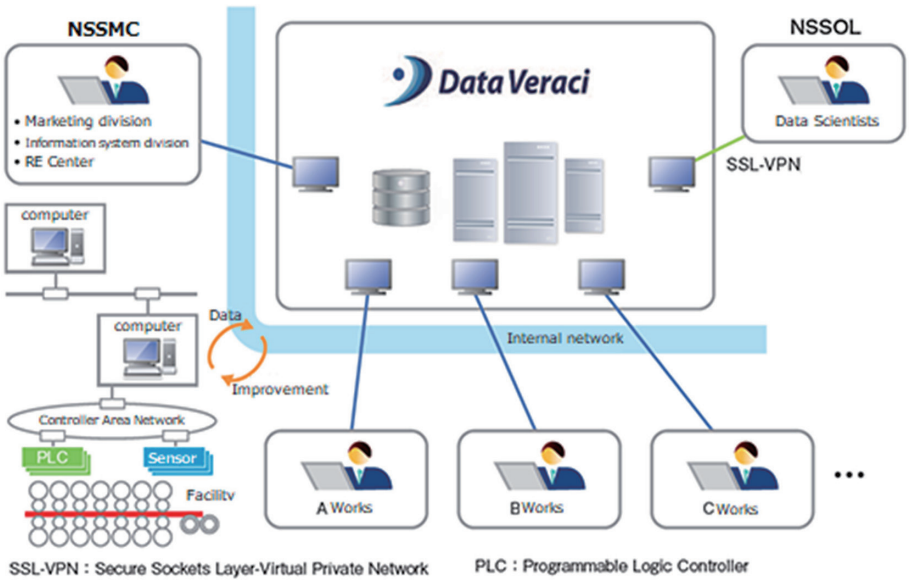

Fig. 2 Company-wide data analysis environment Data Veraci (https://www.nssol.nssmc.com/casestudy/usercase/2373.html)

data needs to be handled flexibly in the pretreatment including data cleansing and the exploratory data analysis (EDA) depending on its properties, in addition to handling data in accordance with predetermined procedures. In such cases, high flexibility where various processing can be made by coding is important. However, such tools are difficult for persons who are new to data analysis and programming, so the contents for learning them are also provided in the environment.

As the data analysis project management tool, Redmine that had been used to manage software development projects formerly was introduced. This tool can record tasks to be carried out and can manage statuses, allowing you to understand who is executing which task and the progress. Usually, various tasks for verifying hypotheses are repeated in data analysis to promote a project, so such task management is very important. In addition, recording tasks visualizes operations that data analysts made, being useful for sharing knowledge between the analysts.

Currently, Data Veraci is used throughout the company as a data analysis integration platform by making the most of its characteristics as a cloud, not only limited to offices and departments. Effects of the introduction of this platform are to make it possible to reduce labors in establishing analysis environments and the lead time to start analysis, to visualize analysis carried out at various sections in the company, and to share knowledge. Sharing knowledge of excellent technical engineers within the company leads to enhancing the organizational ability to analyze data. It is also useful as a measure against the shortage of data analysts that is a recent problem. In addition, the platform allows engineers who work at actual manufacturing sites and who understand equipment operation data analysis deeply to work in cooperation with laboratory engineers who know a wide variety of the latest analysis techniques well, which could solve more difficult problems with business operations.

4.3 Toward the promotion of efficient data use

To promote efficient data use by data analysis technologies in the future, it goes without saying that such platforms are efficiently used and they need to be further improved based on technical trends and needs at actual manufacturing sites. Recently, data analysis technologies have been rapidly advancing, so following such speed from the aspect of platform is an important task. Currently, a virtual container system is used to separate the analysis tool from the platform to make it easier to reform the tool. We would like to improve the customizability of such virtual container system based on needs in order to provide more flexible analysis environments. In addition, not only the data analysis integration platform, but also peripheral systems need to be developed. For example, establishing a scheme that collects business operation data that is essential for data analysis from existing systems and that provides such data in a form that data analysts can handle more easily and a scheme that provides data analysis results more simply as a system will possibly strengthen the linkage between the data analysis platform and business operation systems. These themes will possibly be important in conducting analysis that better matches actual manufacturing sites quickly.

5. Processing Sequence Optimization Computational Engine “Narabikun”[*3]

5.1 Work on optimization technologies

Optimization technologies are used to plan production schedules and operation schedules automatically as support for planning operations. To plan accurate schedules automatically by optimization technologies, establishing optimization problem models that match targets to be planned is required. The Systems Research and Development Center has handled more than 80 models mainly for the manufacturing industry.

The frequently handled model type among these is the scheduling of continuous lines for consecutively processing items one by one, such as rolling and plating processes at steelworks. We, aiming at standardizing problem models for line processing sequences and speeding up the automatic planning, have researched and developed processing sequence optimization computational engine “Narabikun”. This chapter introduces the functions and mechanism of Narabikun (**Fig. 3**).

5.2 Problem models handled by Narabikun

The processing sequence optimization problem for a single line is to determine in what sequence items should be sent to the line in consideration of the times for processing and setting them up. The main objectives are to maximize the production efficiency through the arrangement of items and minimize influence on the quality and delivery delays. In actual application, various constraints are imposed on sequences. They can be classified into the following eight types (a) to (h). Narabikun can handle all of them. (The terms in parentheses are examples of classified constraints.)

(a) Change: Reduce variations between two items to be processed successively (setups, differences in processing specifications).
(b) Time window: Limit the arrangement timing of each item (delivery date, securing of items for starting up the line).
(c) Completion: Determine the completion deadline for all items (operation time).
(d) Priority: Specify the side to be arranged first between two items (sequence to stack partly finished goods).
(e) Interval: Restrict the arrangement interval between two items (insertion of cushioning items for changing the product type).
(f) Continuous amount: Restrict the amount of specific product types to be continuously arranged (carrying-out capacity).
(g) Block amount: Restrict the amount of specific product types to be arranged during a period (decentralization of items with high loads)
(h) Fixing of the head and end: Fix items to be put at the head and end (consideration of settled items).

Where, upper and lower limits for the constraints (e) to (g) can be determined by the user. For the change constraint (a), another cost table can be defined depending on whether the item is before or after the designated one. This function allows change standards for the start section in a lot to be determined differently from the re-

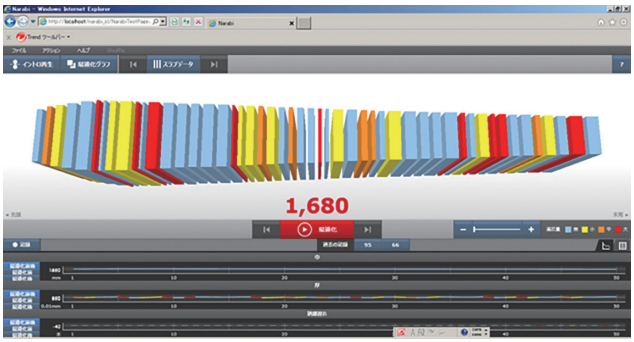

Fig. 3 Example of sequencing in steel rolling

[*3] Narabikun is a registered trademark of NS Solutions Corporation in Japan.

maining section (e.g., coffin type schedule). Narabikun has been applied to tens of lines so far and the constraint types listed above are sufficient to cover almost all actual constraints, so Narabikun has necessary and sufficient functions for handling constraints.

Narabikun scores all violations of constraints and searches a sequence for which the total score is the minimum. In such scoring, the degree of violation can be taken into account. For example, for the time window constraint (b), scores can be determined in proportion to the length of that exceeding a designated period or they can be increased in multiple stages.

5.3 Narabikun algorithm

Mixed integer programming (MIP), genetic algorithm (GA), and simulated annealing (SA) are potential techniques as those to search solutions for the problem. We tried all of these and selected SA as a base of Narabikun since its performance was the best.[5)]

SA is a meta heuristic algorithm in which a neighborhood operation (part of a current solution is changed to obtain the next candidate solution) is repeated many times by narrowing down the degree of allowing operations for changing the solution for the worse gradually to settle down to the optimal solution stochastically.

In searching in SA, neighborhood operations are made several million to tens of millions of times, so it is very important to improve the efficiency of scoring neighborhood solutions. As a characteristic of neighborhood operations, most parts of the sequence of a current solution are the same as that of a neighborhood solution and thereby the degrees of their violations of most constraints are similar. In our computational engine, to make full use of such characteristic, the relationship network between the variable of each item and the constraint(s) related to it is retained; and only constraints that are related to the items for which the sequences were changed in neighborhood operations are extracted to evaluate the differences.

This scheme has improved the speed of Narabikun significantly to make it possible for Narabikun to handle the various constraint types listed above. **Figure 4** shows the benchmark performance for the processing sequence optimization problems based on the number of items simulating actual problems. Although some variations are seen, the computing time is in proportion to the number of items on the whole. The time is approximately three minutes for a large lot (approximately 160 items) and a little less than one minute for smaller lots (less than 50).

5.4 Future task

Narabikun now has a searching capacity sufficient for practical use through continuous improvements to the algorithm and improvements to hardware. The authors are aiming at expanding models to multiple lots and multi-stage processes by making the most of the performance.

Meanwhile, although neighborhood operations have been repeated tens of millions of times in every execution, what type of sequence change operation is made is still based on randomized control. We expect that if the trend of effective operations can be understood by reinforcement learning, this could further speed up the calculation.

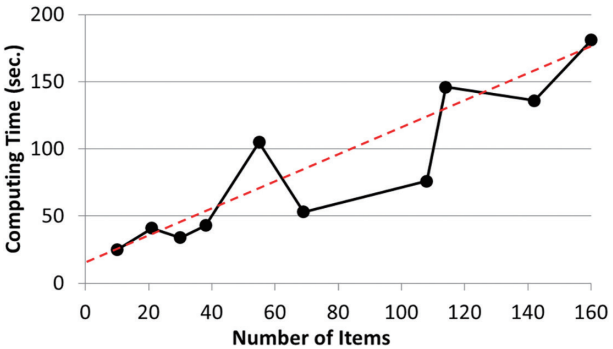

Fig. 4 Computing time for number of items (core i7-4790K 4.00 GHz 1core, using mem. 400 MB)

6. IoX[*4] Platform Supporting Safety Monitoring Systems

6.1 Introduction

Currently, as NSSOL is working to utilize smartphones for business operations, it has started introducing a safety monitoring system to enhance the safety of workers at actual manufacturing sites. This chapter describes the requirements of the safety monitoring system and how the IoX Platform that was developed as an environment to support the system deals with them.

6.2 Requirements of the safety monitoring system

The safety monitoring system (**Fig. 5**) watches the locations, movement, and working environments of workers at factories, plants, and other large-scale facilities. In this system, data transmitted from smartphones and various sensors connected to smartphones needs to be sent to the server; the conditions of the workers need to be judged each time without omission; and an abnormality detected needs to be properly notified. Therefore, even when this system is used by approximately 100 workers, it processes approximately a hundred million records (data) per day. In addition, a security mechanism to handle vital signs and other sensitive information and design to prevent data and processing from being omitted are required.

NSSOL has developed the special system environment IoX Platform to satisfy such requirements that are different from those required for general business operation systems.

6.3 Measures in the IoX Platform

The IoX Platform[6)] has three characteristics listed below to satisfy the afore-mentioned system requirements (**Fig. 6**).

(i) A mechanism to allow resources to be added separately by selecting a functional module that can tolerate high-frequency transmission of a large volume of data and by making each

[*4] IoX is a registered trademark of NS Solutions Corporation in Japan. The term "IoX" is the corrective designation of a concept in which IoT (Internet of Things), where machines and parts are linked to each other, is linked and works together at a high level with IoH (Internet of Humans), where humans are linked to each other via the active use of IT, to produce many excellent results (from https://www.nssol.nssmc.com/ss/iox/).

Fig. 5 System for watching safety (https://www.nssol.nssmc.com/ss/pdf/nssol-ss-IoX-cat-052-01.pdf)

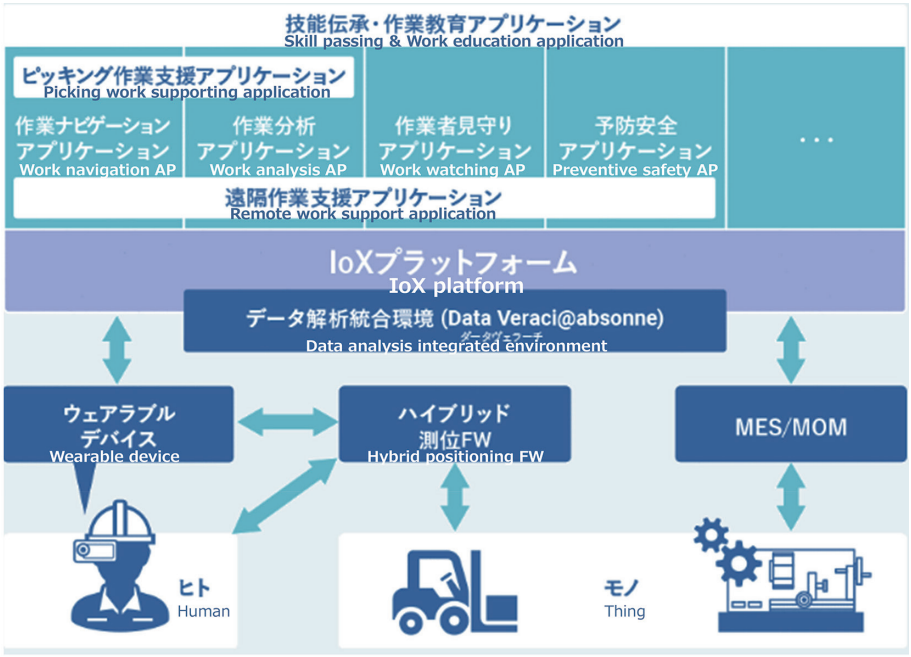

Fig. 6 IoX platform
(https://www.nssol.nssmc.com/ss/iox/)

functional module more independent from others

(ii) A protocol that has been designed considering that even when a failure occurs between divided functional modules, data is not lost

(iii) A cross-sectional security[7] mechanism on the server gateway side and a client device authentication mechanism to exclude data transmission from unexpected devices

In addition, the use of a system in this domain often expands to several hundreds and several thousands in full-scale introduction even when it starts from a trial for several workers, so the configuration needs to have the feature of flexibility so that it can be used from a small scale to a large scale. The IoX Platform's mechanism can handle both large and small scales flexibly because a light Virtual Container system (Docker) and a control mechanism (Kubernetes) for Docker have been introduced in it.

6.4 Toward improvements of actual manufacturing sites by the active use of IoX systems

In the IoX domain, data from factories and equipment, new data on workers that is acquired by equipping them with smartphones and wearable devices, and public data on weather, atmospheric conditions, and temperature are combined to improve the work environments at actual manufacturing sites, safety, and operation efficiency and to hand down techniques to the next generation.

NSSOL is planning to research and develop the IoX Platform under a concept called digital twin[8] as a system environment that supports systems in the IoX domain for which the use will accelerate.

7. Trend and Active Use of Augmented Reality (AR)

7.1 Trend of AR

A technology to superimpose computer information on real-life information in real time to expand human senses (e.g., senses of sight and hearing) is called augmented reality (AR). NSSOL started working on AR in around 2008 to apply it to support work at actual manufacturing sites. In the support of work at actual manufacturing sites using AR, it is ideal to understand the work details of workers and provide information at an appropriate location and at an appropriate timing without delay. To achieve this, various elemental technologies need to be combined, for example, developing devices that do not hinder work much and understanding work details are required. Recently, leading IT companies such as Apple, Google, and Microsoft started implementing such technologies as standard OS functions.[9–11]

7.2 Present conditions of smartglasses (AR glasses)

Currently, smartphones are widely used as devices to use AR, but smartphones occupy hands and thereby they hinder manual work. Smartglasses or AR glasses are wearable eyeglass-type devices with AR functions. Using such devices eliminates the problem mentioned above. Products of smartglasses manufacturers are now into the third and fourth generations. Many improvements have been made: for example, their processing capacity has been improved; the weight has been reduced; the batteries' operating time has become longer; persons who wear normal glasses can wear smartglasses; dustproof and waterproof types are available; and glasses without cables are on the market (**Fig. 7**).

In addition, AR glasses having excellent space perception capability like Microsoft HoloLens have appeared. Work details often strongly relate to worksites, so accurate space perception is an essential technology in work support using AR. Accurate space perception and position estimation have been making it possible to give instructions at accurate positions. However, there are still some problems, for example, the operation time is still a few hours and the size is too large to bring them into manufacturing sites.

7.3 Example active use of smartglasses

A researcher overseas has reported some cases where the introduction of smartglasses into actual manufacturing sites reduced the operation time by 34% (GE) and the annual cost by 900 thousand dollars (Pharma).[12] In Japan, as part of UDCast (information sup-

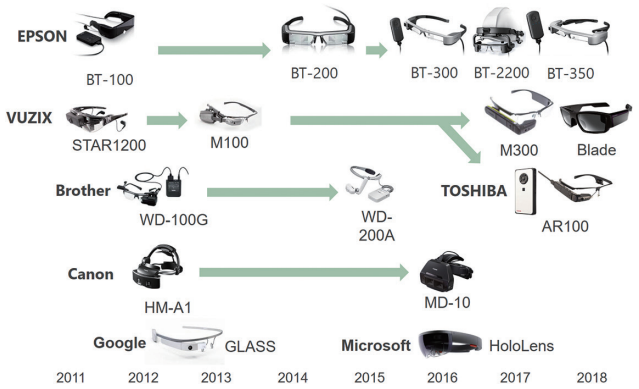

Fig. 7 Evolution of smartglasses

port services for the disabled), a service for displaying subtitles using smartglasses for the hearing impaired is provided at movie theaters nationwide. Meanwhile, there are not many cases where smartglasses are used in business operations on a full-scale basis in Japan and many are still at the level of demonstration experiments. Examples of active use are listed below.

1. Remote work support
   Exchanging images and texts without using hands as an extension of telephones
2. Picking support
   Providing guidance to collect necessary parts efficiently at warehouses and recording work details
3. Full-size simulations
   Checking items in three dimensions in the construction and education sectors when such check is more effective
4. Medical care
   Manipulating without touching from the aspect of sanitation and checking regions in three dimensions in surgery operations

7.4 Future prospect of AR

As mentioned above, it is ideal to have AR provide support automatically depending on workers' work details. However, realizing such function is rather difficult at present. To realize this function, linkage with various types of IoT equipment and the use of AI for understanding work conditions are required. For the former, the next-generation communication technologies (e.g., 5G) and sensor devices need to be used. For the latter, specialized processers are required. NSSOL has been carrying out various projects for such technologies.[13)]

8. Conclusion

The advancement of IT is endless. This paper mainly introduced the technologies that have been applied to the steel industry and steelworks and those that are expected to be applied. Even in the technical sectors introduced in this paper, future advancement is still highly possible and further technological innovation can be expected. As technological innovation accelerates, the cycle in which we understand technologies, use them freely, and apply them needs to be further accelerated, so research and development will become even more important. At the same time, such technologies need to be applied to actual problems and the distance between co-creation activities with customers and research/development needs to be shortened. NSSOL thinks that the speed can be increased by making the most of the characteristics of the Systems Research and Development Center that has both functions for researching and developing technologies and practically using developed technologies.

In addition, it is becoming necessary to use external information and resources to understand technologies and use them efficiently and this trend will possibly become more pronounced. We understand that our accumulated ability to apply technologies and to develop solutions through combination is possibly an element that makes the Systems Research and Development Center different from other companies. NSSOL will continue activities to be an outstanding presence as an organization that will solve technical problems in future technical innovation by combining the use of external resources with our original differentiation element.

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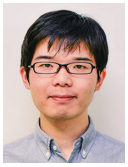

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