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Technology

Factory Smartification: Automated and Remote Manufacturing Operations

Hiroto NAKAYAMA*
Toshio AKAGI
Masataka INOUE
Kohtaroh SAKAI
Shota TAKESHIMA

Abstract

Nippon Steel Corporation has been actively incorporating ICT since the 1960s in various fields such as production, sales, logistics, maintenance, purchasing, and profit management, and has promoted efficient production, automation, and optimization. In addition, we expect to further accelerate the formalization and standardization of our proprietary technologies, including expertise and tacit knowledge by actively utilizing recent various digital technologies in the cooperative area. We also aim to improve labor productivity and stabilize production by utilizing the latest automation and predictive detection technologies. In this paper, we describe in detail the operation support technologies and their application examples at steel worksites, such as automation of heavy equipment operation using image processing and data modeling technology.

1. Introduction

Nippon Steel Corporation has been promoting development to automatically and remotely make judgments and operations (smartification), which have traditionally been made by humans through visual inspections, using recent image processing, and artificial intelligence technology and high-speed stable communication infrastructure. This paper introduces our specific efforts to analyze and visualize actual operations by skilled workers at steelmaking sites and to carry out operations from remote places.

2. Efficient Transfer of Heavy Equipment Operation Techniques Utilized at Steel Worksites

As is the case with other industries, the steel industry also faces issues such as labor shortage due to a declining birthrate and aging population and transfer of skills at manufacturing sites. Nippon Steel has been promoting remote control and automation through digital transformation (DX) of the industrial infrastructure. In order to efficiently transfer heavy equipment operation techniques utilized at steel worksites, Nippon Steel has been working to visualize skilled workers' operations, in cooperation with ExaWizards Inc. that offers various innovations using AI. This section introduces a specific case.

At steelmaking sites, heavy equipment is operated to separate molten steel components and slag, which is produced when grades are adjusted. This task involves the handling of hot melts, the temperature of which exceeds 1 000°C. Accordingly, operators remotely control heavy equipment to separate slag while checking situations with cameras installed at actual sites (**Fig. 1**). In slag separation, as the conditions of hot melts change, judgments by operators based on their knowledge and experience are important. To transfer techniques efficiently, it is necessary to use indexes to instruct actual op-

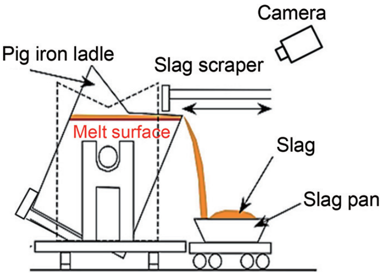

Fig. 1 Outline of slag separation task in steel making process

* Senior Manager, Head of Section, Electrical Engineering Section-II, Electrical Engineering Dept., Systems & Control Engineering Div., Plant Engineering and Facility Management Center
20-1 Shintomi, Futtsu City, Chiba Pref. 293-8511

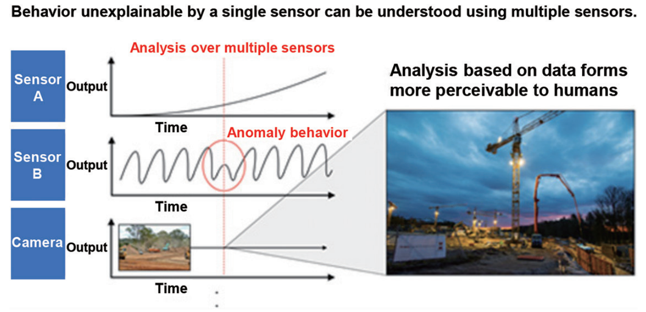

Fig. 2 Outline of understanding operation of experts using multiple forms of data

erations and turn experienced workers' skills and expertise into explicit knowledge.

To that end, we have established a data analysis platform to link various information assets: sensor data such as position of the end effector of heavy equipment at actual sites and its speed, video data showing slag separation operation conditions and melt states, and operation information including processing dates and time and information on operators.

Analyzing the skill levels of operators involves visualizing the operation techniques of experienced workers who have been working at the company for ten years or more (**Fig. 2**), which enables providing operation support so that even new workers can perform operations at the same level as experienced workers. This approach is expected to make the quality of operations uniform regardless of the skill levels of workers.

3. Quantification of Tacit Knowledge by AI Modeling

Nippon Steel aims at smarter manufacturing and innovative evolution of its manufacturing capabilities for the purpose of enhancing its business competitiveness by fully utilizing data and digital technologies. The Systems & Control Engineering Division intends to efficiently promote the smartification of manufacturing through high-level utilization of digital technologies, such as AI and IoT, while cooperating with external companies. The division is currently focused on automating operations to discharge molten iron from TPCs.

In the molten iron discharge operation from TPCs in the steelmaking process, the pig iron that has been melted is transferred from a Torpedo Car (TPC) to a molten iron ladle. The operator controls the tilting angle of the TPC to discharge the molten iron in such a way that the weight of the molten iron in the ladle does not exceed the target value (**Fig. 3**).

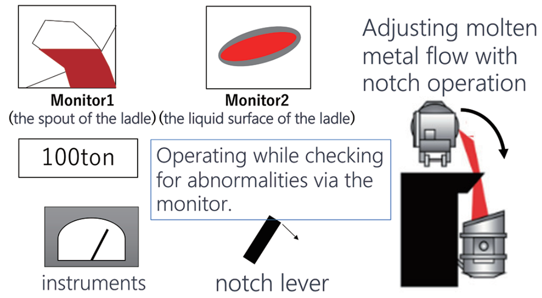

Fig. 3 Overview of operations

With regard to these operations, Nippon Steel cooperated with an AI startup company to quantify operators' tacit knowledge and form an AI model. These tasks essentially required analysis and classification from the perspective of processes. Accordingly, to complete the AI model, Nippon Steel periodically discussed with the AI startup company to check whether the model matched the knowledge of operators as required. To implement the developed model into our system, expertise on system engineering in steelmaking was crucial, and therefore we prioritized efficient progress through collaboration not only with the AI startup company, but also with partnering companies within Nippon Steel.

4. Remote Control of Cranes

In preparation for a possible labor shortage in the future due to a declining birthrate and aging population, Nippon Steel has been developing labor saving technologies and one such technology is to control cranes automatically and remotely. Application of this technology to actual machines has been discussed and some systems were actually introduced. However, the specifications were determined for each project and custom-made systems were used, which increased the costs and prevented the use of such systems from expanding. To resolve such issues, in this crane remote control development, a commercially available device was used to establish functions necessary for remote control while keeping the system establishment cost low.

Remote control of cranes refers to the operation of cranes from places separate from the actual sites where the cranes work; no operators get on the cranes and accompany them. To save labor through remote control, innovation is needed to turn operations that used to be directly carried out by operators at actual sites to those that are performed by a single operator by controlling multiple cranes from an operating room separate from the actual sites (**Fig. 4**).

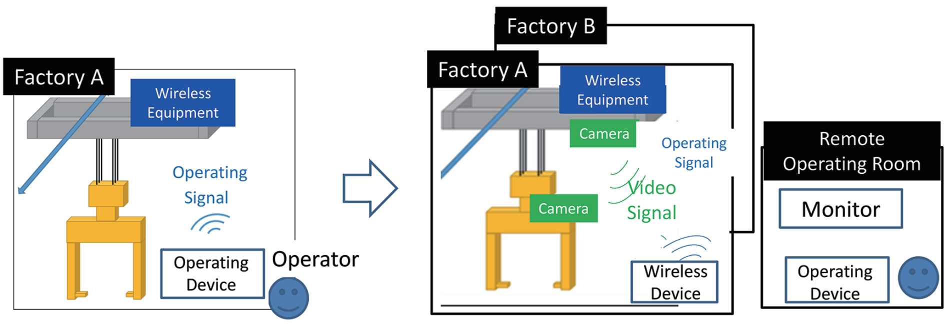

Fig. 4 Outline of crane remote control system

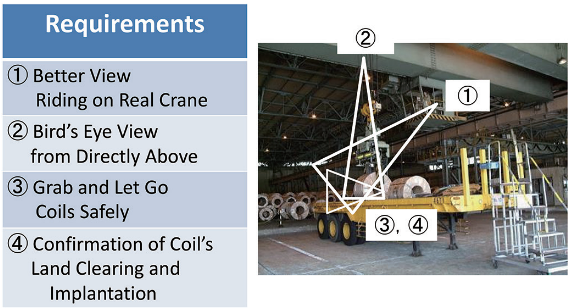

Fig. 5 Requirements from user

Fig. 6 Image of experiment

For innovation in remote control, information that operators used to obtain via their senses should be able to be shown as camera video images and delay in the communications should not pose problems. To satisfy the needs for remote control, we tackled the two tasks listed below for the aforementioned requirements:

1 Optimization of the number of cameras to be installed onto a crane and their locations
2 Evaluation of the influence of delay in video and operations

Regarding task 1, requirements from actual sites were organized (**Fig. 5**) and how many cameras would be required to secure a necessary visual field and their locations were tested. The test revealed that the necessary number is five and specific additional information is required.

Regarding task 2, video and operations were evaluated by changing the combinations of cranes and operators (**Fig. 6**). It was found that, regardless of crane types and operators' experience, if delay in video and operations could be kept within a certain period of time, remote control would hold well.

We completed the basic development at the completion of the aforementioned two tasks.

We are now conducting durability and operation tests to enhance the workability by allowing operators to familiarize themselves with the system toward application of the system to actual machines.

5. Conclusion

This paper introduced the cases where conventional operations were turned into operations to be automatically or remotely performed using recent image processing and AI technologies, in cooperation with an external company that exceled in such technologies. We will further promote these approaches also in the future to turn skilled workers' expertise into explicit knowledge, save labor, and automate operations at an increasingly fast pace.

Hiroto NAKAYAMA
Senior Manager, Head of Section
Electrical Engineering Section-II
Electrical Engineering Dept.
Systems & Control Engineering Div.
Plant Engineering and Facility Management Center
20-1 Shintomi, Futtsu City, Chiba Pref. 293-8511

Toshio AKAGI
Principal Researcher
Intelligent Algorithm Research Center
(Currently General Manager, Developing & Planning Division, Electrical Instrumentation Unit
Nippon Steel Texeng. Co., Ltd.)

Masataka INOUE
Senior Manager
Control Development Section
Systems & Control Technology Dept.
Systems & Control Engineering Div.
Plant Engineering and Facility Management Center

Kohtaroh SAKAI
Control Development Section
Systems & Control Technology Dept.
Systems & Control Engineering Div.
Plant Engineering and Facility Management Center

Shota TAKESHIMA
Senior Manager
Digital Innovation Div.