Development of Control Failure Recovery Support System

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Abstract:

JFE Steel has constructed a control fault recovery support system (J-mAIster™) applying IBM Watson™ (cognitive technology) as a support tool to retrieve information such as past fault reports, work standards, and manufacturers' manuals stored in the integrated maintenance system, etc. and to provide action guidance, etc. for fault recovery. After the verification in actual machine was carried out in the main cold rolling lines of West Japan Works, it was introduced to all steel works and factories in September, 2018. In this report, the outline of J-mAIster™ is described.

1. Introduction

JFE Steel Corporation is a steel manufacturer that produces a wide variety of products in large quantities and has major production bases throughout Japan, as shown in **Figure 1**. At these production sites, the lines are operated 24 hours a day, 365 days a year to produce steel products. Although JFE Steel was established in 2003 through the integration of Kawasaki Steel Corporation and NKK Corporation, and the production lines at each site include various types; while some lines had been in operation for several decades since startup, other lines were constructed with state-of-the-art technology based on recent customer requirements. To ensure stable operation of these lines, the know-how, experience and other knowledge of skilled employees accumulated over many years is indispensable, while the acquisition of the knowledge, techniques and skills needed to control the latest equipment and equipment is also essential. However, especially when trouble occurs in electrical and control systems, it is difficult for employees without many years of experience to discover the cause and determine how to deal with it simply by observing the condition of occurrence, and as veterans have retired, the generational change of employees in recent years has given rise to problems such as the extended time necessary to recover normal operation. To solve these problems, JFE Steel developed a support system utilizing IBM Watson™ (hereinafter, Watson)[1].

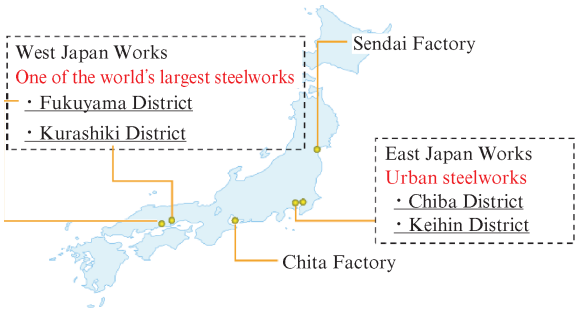

Fig. 1 Main steel works

2. Overview of Control Failure Recovery Support System

2.1 Purpose of Development

2.1.1 Challenges

At manufacturing sites in JFE Steel, the company has established a maintenance shift group as a workplace that is responsible for dealing with electrical and control problems. Since this maintenance shift group must provide a 24 hour failure recovery response, which requires a wide range of knowledge and experience, veteran personnel were assigned to this workplace until now. However, the recent generational change has made it difficult to maintain a group with an all-veteran composition, and inexperienced personnel and young employees have unavoidably been assigned to these duties. This has increased both the time required for repair and recovery and the number of times that

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experts on regular duty have been called in at night.

2.1.2 Proposals for addressing issues

Under these circumstances, the methods of failure analysis and failure response by veteran employees were investigated. Because it was found that the response to trouble by veterans was largely based on know-how accumulated over many years, that is, past experience and abundant knowledge, technology and skills, the establishment of an environment where such information could be visualized and utilized was considered to be an effective countermeasure. In fact, because each manufacturing site possesses a large amount of information such as failure reports and operating procedures, which had not been shared between sites, a project was started in 2016 with the aim of constructing a system that would enable centralized management and easy search and browsing by anyone.

2.2 System Overview

2.2.1 Survey of current status

First, we investigated the relevant data that the maintenance shift group uses in failure recovery work. The data were classified into more than 40 types, as shown in **Figure 2**. Although only about half of the data were used frequently in the initial response in the failure recovery work, the amount of target data was enormous, and it was difficult to find valid data.

2.2.2 Review of search engines

The Control Technology Subcommittee had been studying the introduction of search engines from domestic vendors for effective use of the above-mentioned maintenance information, but determined that it would difficult to find useful information due to the large number of results that were output when all documents containing search strings were searched. In this context, IBM announced Watson, which has a function that narrows down the target further based on the search history and a function that judges the intention of the user (natural language classification), which we thought would make it easy to search for useful information. Therefore, we constructed a prototype capable of real line simulation, studied whether to adopt it, and decided to adopt it because good results were obtained.

2.2.3 System configuration

Because the maintenance information held by JFE Steel was dispersed in various locations, such as the integrated maintenance system and document servers of each manufacturing site, it was necessary to centralize and manage this data in a unified manner. As an aggregation method, we decided to utilize the public cloud service "box™" because building separate interfaces was deemed to be inefficient. The application server was built on the J-OSCloud, the private cloud service of JFE Steel, to enable fast, advanced Watson searches. To improve user convenience, the natural language classification function can also be used by utilizing IBM™ Cloud. The system configuration is shown in **Figure 3**, and allows users at each manufacturing site to easily and freely add and modify maintenance-related data at any time.

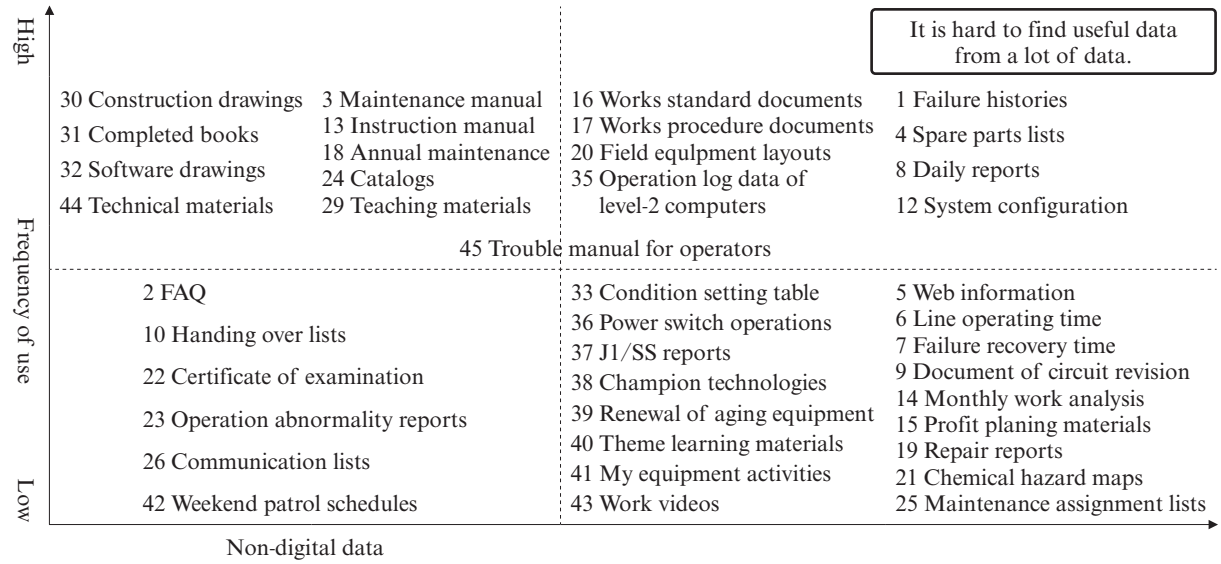

Fig. 2 Data related to fault recovery

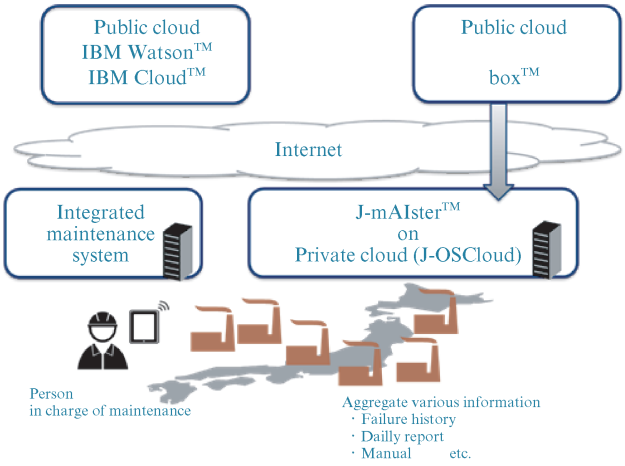

Fig. 3 System configuration of J-mAIster™

2.3 System Features

2.3.1 Basic features

This section describes the two basic functions of the newly-developed system (see **Figure 4**). The first is the ability to perform fuzzy searches. When a user enters the content to be investigated in a conversational format, the system automatically extracts the search keywords by a natural language classification function and also automatically identifies the categories of documents to be searched in order to extract more relevant documents. Second, when the search results are displayed, they are prioritized to make it easier to find useful information. These functions are described in further detail in the following Section 2.3.2.

2.3.2 Details of basic features

The TF-IDF method[2] is used for the display order of search results. The idea of the TF-IDF method is that if a word with a characteristically high occurrence level in a document is given as a search keyword, the document is ranked higher in the search results. Specific formulas and examples are shown below.

(1) Meanings of TF and IDF

Term Frequency (TF): The frequency with which the word (t) occurs in a document.

*Frequently occurring words in a document d = Characteristic words indicating a document d

IDF (Inverse Document Frequency): The inverse of the number of documents in which the word (t) appears.

*Words appearing in many documents = Not characteristic words indicating a document d

By finding TF and IDF, it is possible to calculate the degree of feature of the word (t) in the document.

*Due to the nature of the IDF formula described below, words appearing in many documents have smaller IDF values.

(2) Formula for calculating TF value

$tf\,(t, d) = n_{t, d}/\Sigma_{s \in d} n_{s, d}$

Here,

$tf\,(t, d)$: TF value (frequency) of word t in document d

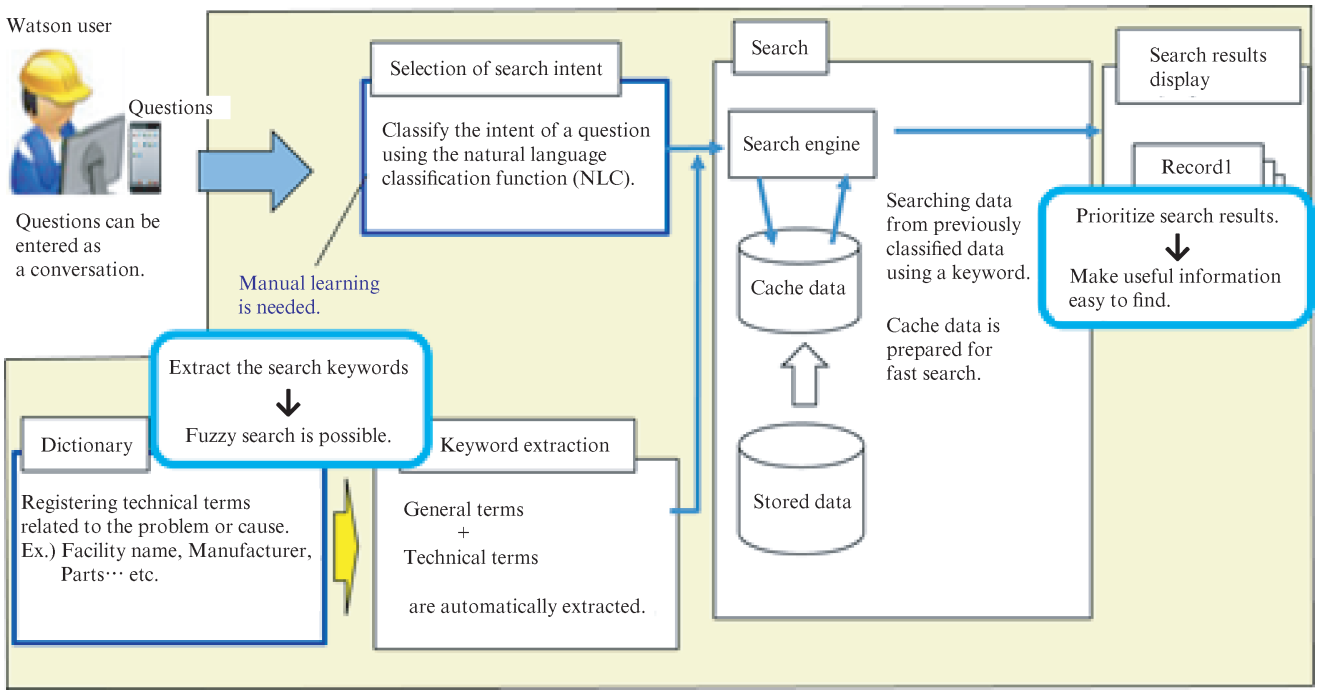

Fig. 4 Basic functions of J-mAIster™

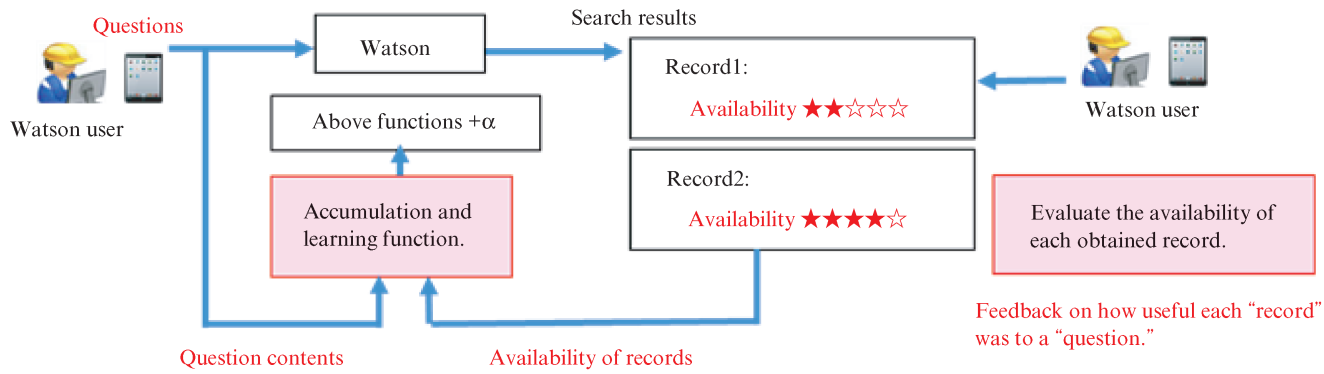

Fig. 5 Improving learning capabilities and calculating usefulness

$n_{t,d}$: Number of times word t occurs in document d
$\Sigma_{s \in d} n_{s,d}$: Sum of occurrences of all words in document d

Example of calculation: If the word "Inverter" appears 10 times in a fault history consisting of 200 words, the TF value of "Inverter" in that fault history is 10/200 = 0.05.

(3) Formula for calculating IDF value

$idf(t) = \log N/dt(t) + 1$

*Calculated as a logarithm to reduce the effect of a larger document size; + 1 to prevent *idf* from becoming zero.

Here,

idf (t): IDF value of word t
df (t): Number of documents in which word t occurs (document frequency)
N: Total number of documents

Example of calculation: If "Inverter" appears in 100 of 10 000 documents, the IDF value of "Inverter" is log 10 000 - log 100 + 1 = 4 – 2 + 1 = 3.

(4) Actual example[3)]

① Assumptions

In 10 000 documents, the document frequency (DF) of the next 2 words shall be

df (Inverter) = 100, *df* (Cable) = 200
idf (Inverter) = log 10 000 – log 100 + 1
= 4 – 2 + 1 = 3
idf (Cable) = log 10 000 – log 200 + 1
= log10 000 – log100 – log 2 + 1
= 4 – 2 – 0.301 + 1 = 2.699

② Calculation of TF values

Suppose there are 200 words in a document d and "Inverter" appears 10 times and "Cable" appears 11 times.

tf (Inverter, d) = 10/200 = 0.05
tf (Cable, d) = 11/200 = 0.055

③ Calculation of degree of features

The characteristics of "Inverter" and "Cable" in document d are obtained as follows:

tf (Inverter, d) / *idf* (Inverter) = 0.05 / 3 = 0.15
tf (Cable, d) / *idf* (Cable) = 0.055 / 2.699
= 0.14795

④ Display order

In this document set, "Inverter" appears less frequently than "Cable" in a given document d, but the degree of feature representing document d is high ⇒ displayed above "Inverter."

2.3.3 Introduction of individual features

In this system, the concept of "usefulness" is defined and implemented as an inherent index value. In addition to the "frequency" and "correlation" obtained by "Watson," we introduced "usefulness" as an index value based on the accumulated maintenance know-how, and constructed a mechanism that can change and enhance logic such as the display order of search results by continuous tuning. An overview of this is shown in **Figure 5**.

3. Conclusion

Following the introduction of this system, many cases in which the recovery time for similar failures was reduced by about 20 to 30 % compared with the conventional system have been reported by each manufacturing site. Thus, it can be said that the support tool was constructed as originally intended. It is also being applied to the operational sector, contributing to the stable supply of steel products.

Future issues are the uptake of nonelectronic information and its application to preventive maintenance. We hope to solve these problems and improve the system to be more effective.

Acknowledgment

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