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Machine Learning of Ambiguous Sentences and Analysis of Relation between Ambiguous Sentences and Diagrams in Technical Manual for Tacit Knowledge Acquisition

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Abstract

Many companies create manuals to inherit the technology. Manuals contain a lot of information, but few are focused on tacit knowledge. Against this background, this research has two purposes, targeting manuals. First, it is to judge ambiguous sentences for mining tacit knowledge. Second, it is to clarify relation between ambiguous sentences and diagrams for mining tacit knowledge. This study was conducted with maintenance of railway rolling stock as the subject. At first, to confirm the hypothesis that ambiguous sentences include tacit knowledge, we compared result of mining by human and by machine learning. We obtained the results that we can recognize the ambiguous sentences by machine learning with high accuracy. The most striking observation to emerge from this data analysis was that ambiguous sentences can identified not only by adjectives and adverbs but also nouns, post positional particle, or conjunctions. Secondly, since many diagrams are used in the manual, it is thought that there were clues to mining tacit knowledge in the diagrams. As a result, it was found that there is a correlation between ambiguous sentences and diagrams.

Keywords: ambiguous sentences, machine learning, technical manual, correlation, diagrams

1 Introduction

With the retirement of the baby boomer generation, technology inheritance in companies has become a problem. In particular, companies such as electric power and railways, which have a large number of facilities and are obsolete, are trying to pass on maintenance technologies through mechanization, automation, and manualization. It is the current situation that is beginning to be done. In the local railway business in Japan, cost reductions such as replacement with next-generation trains that keep running costs down, automation and mechanization are being promoted as measures to improve the deficit of the railway business due to population decline

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and passenger numbers decrease. In such a process, the manuals that have become a mere shell of have been flooded, and the delicate judgment of engineers is being lost. In order to supplement these imperfections, many companies are trying to develop a manual that replaces the judgment of engineers with a high safety factor. However, there is a possibility of inefficient management such as wasted material costs, and it must be said that the existing value of engineers will be reduced, which will adversely affect corporate management in the medium to long term.

With the aforementioned background, research on mechanization and automation has been actively conducted since the past. In order to pass on the knowledge and skills of engineers, knowledge engineering and knowledge management have made it possible to techniques for re-arranging knowledge, such as conversion of tacit knowledge to formal knowledge, have been devised and applied.

The SECI model of knowledge management by Nonaka and Takeuchi [9] is widely known as a basic method of knowledge creation. The knowledge conversion process is classified into four modes, as shown in Figure. 1, of combination, externalization, internalization and socialization. Socialization is the process of creating tacit knowledge of a group from tacit knowledge of an individual. Externalization is the process of creating explicit knowledge from tacit knowledge. The process of creating systematic formal knowledge from formal knowledge. Internalization refers to the process of creating tacit knowledge from formal intelligence.

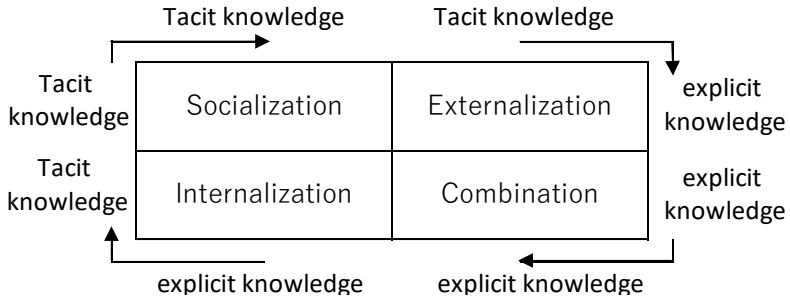

Figure 1 : Knowledge conversion modes

Many companies are making manuals for soclialization and externalization of knowledge about work procedures (Figure. 2). However, there is a possibility that the manual is made without fully understanding the issues of tacit knowledge. Complex technology at the work site may not be expressed in words. There are cases where it is illusion as if it is formalized simply by expressing in an ambiguous language that is difficult to describe accurately. Then, technology cannot be passed down correctly. Even if a manual were made, formalization has not been completed yet. A major cause of the failure of technology inheritance is the misunderstanding that knowledge could be formalized by completing the manual. In this paper, we consider that there is tacit knowledge in an ambiguous sentence in the manual. By extracting the ambiguous sentences in the manual mechanically, it is possible to know what items have tacit knowledge. By correcting ambiguous parts that have been found, it can be corrected to a more practical manual.

In this paper, we try to derive a method for extracting ambiguous sentences in a manual by machine learning. Many studies on general text ambiguity have already been conducted, but no research has analyzed the causes of ambiguity in highly specialized texts such as technical

manuals. First, as a clue to start this research, looking at the technology succession of coal mine companies in the heyday when there were enough workers, young workers often created manuals. For expressions that include adjectives such as "light" and "strong" in the indicated work procedure, and expressions that lack the perspective of "how" such as "be careful" and "confirm". Complemented by the addition of young engineers, and we can know the ambiguity that remains depending on the type of part of speech. By extracting ambiguous sentences from a large number of sentences by machine learning, the tacit knowledge contained in the existing manual can be clarified, which can lead to the update and improvement of the manual. As mentioned above, sentences that young engineers feel ambiguous when reading the manual are not only adjectives and adverbs that are said to cause ambiguity when included in general sentences, but also technical terms and technical sentences. The presence of the part of speech may have an effect. Focusing on that, we tried to identify by machine learning using only words with specific part of speech. Furthermore, focusing on the structure of the manual, it can be seen that various figures and tables are used in the manual. Some diagrams have a big meaning by themselves, while others are used to supplement the ambiguous sentences. This paper analyzes the relation between ambiguous sentences derived from tacit knowledge and diagrams.

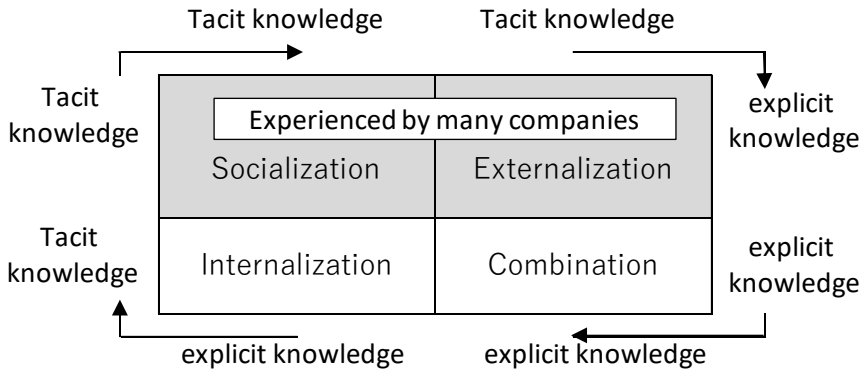

Figure 2 : Actual state of technology succession of companies

2 Related Work

We investigated previous research on the ambiguity of manuals focused on in this paper and the structure of manuals. The previous research focused on components is introduced below. Sannami et al. [12] focused on manuals for mobile phones for the elderly, and analyzed the components of the manuals. The response to visual acuity and cognitive decline due to aging in the elderly has almost been realized. It has been found that the ability to respond to color perception due to a decrease in the ability to concentrate, the sustainability of attention, and the decrease in memory ability due to a decrease in judgment are still in the process of developing, and the response situation varies depending on the manufacturer. It was suggested that the concrete process of organizing the characteristics of the manual and assuming the combination of the components and the situation of the corresponding manual might be effective in the manual creation. It showed that there is a specific process for identifying problems in actual work resulting from changes in characteristics, and how to implement these responses with the components of the

manual. Harada and Endo [2] al. analyzed whether a video-based manual is useful as a human learning tool. Compared to images, manuals using video are more effective for learners in three-dimensional tasks. However, it was found that there was no advantage in using two-dimensional, "non-intuitive movements" by using video. After that, it was suggested that manuals using still images may be superior to manuals using moving images in the same task without using manuals. Negishi et al. [8] focused on differences in technology and culture between Japan and China, and considered the characteristics of technology transfer. The textbooks of schools that greatly affect the formation of culture and the instruction manuals for appliances widely required for daily life were analyzed. As a result, it was found that there was a difference in the ratio between the figure and the text in Japanese-Chinese technology transfer, and that China used a lot of letters and Japan used a lot of figures and illustrations. Since the written language has been unified since the Qin Dynasty (about 2200 years ago) and spoken language was unified only in 1957 (about 50 years ago), it was easy to communicate in written language than communication in spoken language. However, in Japan, the level of education is relatively constant, and it is thought that the same interpretation and image can be shared in both spoken and written expressions. Therefore, when Japanese pass on technology to Chinese, it is highly possible that each person will have a different image and meaning interpretation based only on spoken language and diagrams. For this reason, it is concluded that it is necessary to sequentially confirm understanding using letters.

Research on tacit knowledge extraction has attracted a lot of attention since old days[11]. An attempt to extract tacit knowledge in various areas and their experiences are spoken [6], [14]–[16]. In this research, we focus on ambiguous sentences, and consider that tacit sentences are included in ambiguous sentences, which is recognized by machine learning. Research of [6], [15] have the similar approach of mechanical detection. There, the subject is a redundant sentence, which is different from the purpose of our study. In this paper, we analyzed how the type of part of speech of words affects ambiguity. Oda's research [10] on degree expression can be considered a typical example of ambiguous expression. Moreover, in this paper, it focus on the technical manual in order to examine the relation between ambiguous sentences and diagrams that try to express tacit knowledge that is indispensable for technology succession, but various studies have been done to examine the importance of diagrams in documents. Iwatsuki [17] clarified the effect of diagrams that show the main points of sentences for comprehension of explanations. Specifically, we made a college student with no specialized knowledge read the explanation about the medicine, and confirmed the effect in each case of a diagram and a summary that summarizes the main points of the sentence. It was shown that both the figure and the summary sentence facilitate the reproduction of the information of the main points in the sentence, and further that the figure supplement the relation not explicitly written in each sentence rather than the summary sentence. Iwatsuki think that diagrams have property that can express relations that are not explicitly written in the text by expressing information positionally, and it is effectively for reasoning clarifying implicit relations in comparison with text. The role of these figures and tables is to promote understanding of the text and has a strong implication of re-recognizing important matters, but in this paper, we pay attention to the possibility that the figures and tables play a role of complementing incomplete and ambiguous sentences. It is a study that reveals blind spots in technical field work.

3 Utilization of Existing Manuals

OJT-style education is known to use the SECI model for knowledge sharing in the nursing industry and pharmaceutical companies. However, in many companies, a useful cycle for technology transfer is not established, and it is assumed that manuals that have become a mere shell of are inundated. As a result of the retirement of many engineers born in the three years from 1947 to 1949, right after the Second World War, there was a problem of technology succession. In fact, it is becoming too late to take over useful knowledge and skills directly from skilled engineers. Therefore, in order to realize reliable and swift technology transfer, companies that have reached the age of mass retirement have left many technical books, manuals, and educational materials.

In this paper, we believe that ambiguous sentences have tacit knowledge. Mechanical identification of ambiguous sentences and revealing the relation between ambiguous sentences and diagrams that cannot be expressed in the language are the first steps in extracting the inheritance of technology from many existing manuals.

4 Dataset

Japanese railway companies formed a working group to improve the maintenance activities of bogie/wheelset. The working group consists of field supervisors and chief workers of major railway operators in Japan. They compiled and published a manual book [3] for maintenance of bogie/wheelset.

Compared to the books compiled in the past, this manual is a book that was produced for workers from the viewpoint of technology inheritance. In this study, this manual was the subject of analysis. This manual consists of 11 chapters. Among them, Chapter 4 explains in detail the outline, type and structure of each part of the bogie and wheelset. The ambiguous sentences targeted in this study are 212 sentences including the adjectives and adverbs in Chapter 4. This is because it is clear that the sentence containing the adjective and the adverb is ambiguous. From these 212 sentences, we asked two engineers A and B to judge whether the sentences were ambiguous, and used them as machine learning training data. Table 1 shows the Bogie maintenance experience of engineers A and B.

The judgment of the two engineers is as shown in Table 2. The coincidence coefficient was 0.61, indicating a high coincidence rate. In this paper, we consider that tacit knowledge is potentially included in sentences that new engineers feel ambiguous. Therefore, in order to cover the object as widely as possible, machine learning was applied using 160 sentences, at least one of which was determined to be ambiguous, as positive examples.

Table 1 : Experience of subjects

	Engineer Experience	Educational background	Experience		
			Bogie maintenace	Maintenance (exclusive of bogie)	Field manager
subject A	12 years	college graduate	0 month	4 years	None
subject B	8 years	master's degree	4 months	1 year	1 year

Table 2 : Human judgement

		subject A		total
		ambiguous	unambiguous	
suject B	ambiguous	79	13	92
	unambiguous	68	52	120
total		147	65	212

5 Document Vectorization with Limited Parts of Speech

The discrimination performance was determined with 160 sentences that were judged as ambiguous by at least one of the two subjects as positive examples and the remaining 52 sentences as negative examples. SVM-light was used as a machine learning tool, and discrimination performance was obtained by 5-fold cross validation. Since the subject of this research is the difference of the ambiguous sentence recognition by the part-of-speech, the experiment was conducted by vectorizing the target sentence limited to each part of speech. However, because there were only 7 auxiliary verbs, they were excluded. Specifically, eight types of experiments were conducted for the part of speech shown in Table 3.

Table 3 : Eight datasets of experiments

count	abbreviation	part-of-speech
1014	word	word
860	noun	noun
153	verb	verb
79	adj+adv	adjective and adverb
42	adj	adjectibe
39	ppp	post positional particle
37	adv	adverb
23	con	conjunction

6 Result of Machine Learning Experiment

For machine learning, we used SVM-light, an implementation of SVM (support vector machine), which is known to be effective for document classification. As Kernel, experiments were performed with a linear kernel, a polynomial kernel of 2, 3, 4 and 5th order and a Gaussian kernel. We conducted the grid search for C-parameter and gamma-parameter for a linear kernel, a polynomial kernel and a Gaussian kernel with the range of 0.001, 0.01, 0.1, 1, 10, 100,1000. Table 4, Table 5, Figure. 3 and Figure. 4 show the discrimination performance (F1score and accuracy) at

the optimum parameters for each part of speech and kernel. Table 4 and Figure. 3 show the cases where accuracy is 0.65 or higher and the discrimination performance is high. Table 5 and Figure. 4 show the case of low discrimination performance with accuracy less than 0.65.

First, in Figure. 3 and Table 4, the top two part-of-speech, i.e. Noun and Word, have 87% of F1-score and 77% of accuracy. This indicates that mechanical identification of ambiguous sentences is possible with sufficiently high accuracy. Since Noun is included as part of Word, we expected that Word would have higher discrimination performance. Furthermore, in general sentences, ambiguity is often expressed by Adjectives and Adverbs, so that the discrimination performance is highest when all words are used. Although there was not much difference, it was unexpected that Noun had the highest discrimination performance. However, since Noun, Adjective, and Adverb alone have almost the same discrimination performance, it is thought that each contains the cause of ambiguity in this manual.

Common causes of ambiguity in sentences are known as word ambiguity, complex dependency, omission of subject as a Japanese feature, and heavy use of conjunction. However, the document that is the subject of analysis in this paper is technical texts in a special field, and it is the expert group that created the texts. Therefore, it was unexpected that the discrimination performance in post positional particles and conjunction was in the top in the part-of-speech table and figure of the discrimination performance.

Table 4 : Prediction performance W.R.T part-of-speech (GOOD)

POS	kernel	C	gamma	F1-score	accuracy
noun	rbf	10	0.1	0.8689	0.7738
word	rbf	0.001	1	0.8663	0.7695
adv	rbf	1	1	0.8627	0.7638
adv+adj	rbf	1	1	0.8595	0.7593
adj	rbf	1000	0.1	0.8597	0.7551
ppp	rbf	1000	0.001	0.8534	0.7462
noun	pol5	1000	.	0.8375	0.7452
word	lin	1000	.	0.8282	0.7446
adj+adv	pol3	0.01	.	0.8157	0.7360
word	pol4	1000	.	0.8225	0.7260
con	rbf	100	10	0.8368	0.7239
adj+adv	lin	0.01	.	0.7964	0.7136
ppp	lin	0.001	.	0.8033	0.6950
noun	lin	1000	.	0.7902	0.6886

Table 5 : Prediction performance W.R.T part-of-speech (POOR)

POS	kernel	C	gamma	F1-score	accuracy
ppp	pol3	100 .		0.7115	0.6206
veb	lin	0.001 .		0.7329	0.6189
verb	pol4	1000 .		0.6960	0.6073
adj	lin	0.01 .		0.6825	0.5957
adj	pol4	0.01 .		0.6636	0.5805
verb	rbf	0.001	0.001	0.5141	0.5485
adv	pol4	0.01 .		0.4087	0.4711
adv	lin	10 .		0.2411	0.3449
con	pol5	1 .		0.0371	0.2593
con	lin	10 .		0.0371	0.2593

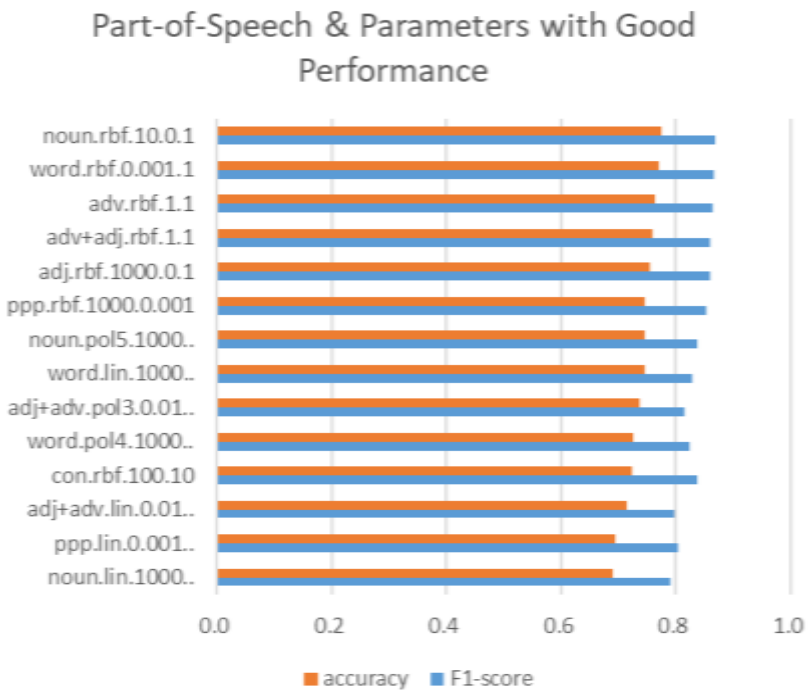

Figure 3 : Part-of-speech with good performance

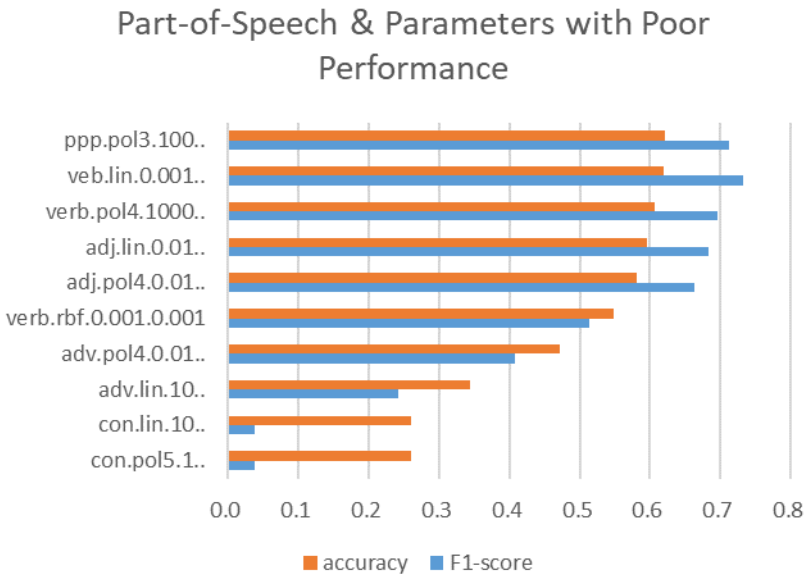

Figure 4 : Part-of-speech with pood performance

7 Prediction Performance by Word Embedding

Word embedding is attracting attention as a new method of capturing the meaning of words. In this paper, in order to verify the discrimination performance evaluation, we also conducted an experiment in the case of vectorization by word embedding. Specifically, we conducted experiments with word embedding using word2vec [5] and BERT [1]. For word2vec, the pretrained model by [13] was used, and for BERT, the pretrained model by [4] was used. The word2vec dimension is 200 dimensions, and the BERT model is 768 dimensions. As can be seen from Table 6, the vectorization focusing on the words and parts of speech described in the previous section can achieve discrimination performance as high as that of the distributed representation.

Table 6 : Performance by word embedding

word embedding	machine learning	parameters	F1-score	accuracy
w2v	svm linear	C=1.0	0.7992	0.6935
w2v	svm rbf	C=1.0 & gamma=0.01	0.8589	0.7596
w2v	NN (3 layered)	hidden_node=512	0.8155	0.7221
BERT	svm linar	C=1.0	0.7810	0.6743
BERT	SVM rbf	C=1. 0& gamma=0.01	0.8596	0.7595
BERT	NN (3 layered)	hidden_node=512	0.8306	0.7312

8 Correlation between Ambiguous Sentences and Diagrams

Since a large number of figures and tables are used in the manuals for bogie/wheelset, we investigated whether the figures and tables disambiguate ambiguous sentences. As a result, we found that the figures and tables contribute to the disambiguation.Moreover, since there are multiple figures and tables used for complementation and they exist over multiple terms, it hypothesized that ambiguous sentences and figures may have a proportional relation. First, with regard to the ambiguity of ambiguous sentences, we examined the charts that helped to resolve the ambiguity, and tabulated each section and section. Figure 5 shows the relation between ambiguous sentences and figures focusing on terms, and Figure 6 shows the relation between ambiguous sentences and figures focusing on sections. A proportional relation was confirmed in both figures. For comparison, we also confirmed the relation with figures for unambiguous sentences. Figure 7 shows the relation between unambiguous sentences and figures focusing on the terms, and Figure 8 shows the relation between unambiguous sentences and figures focusing on the sections.

Table 7 shows the correlation coefficient of each relation. Looking at the term, for ex-ample, indicated as 4.1.1, there was a strong positive correlation between the ambiguous sentence and the diagram, and the unambiguous sentence and the diagram. However, in the section, for example shown as 4.1, there is a strong positive correlation between the ambiguous sentence and the diagram as shown in Figure 6, but there is no correlation between the unambiguous sentence and the chart as shown in Figure 8. As shown in Figure 9, the reason seems to be that not only the diagrams in the same term but also the diagrams in the section are widely involved when the ambiguous sentences are supplemented by the diagrams.

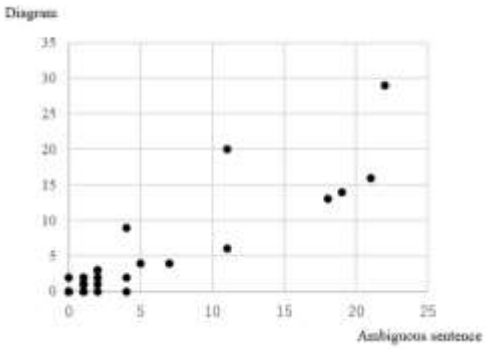

Figure 5: Relation between ambiguous sentences and figures in terms

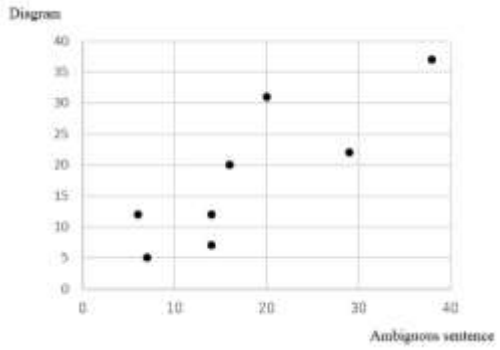

Figure 6: Relation between ambiguous sentences and figures in sections

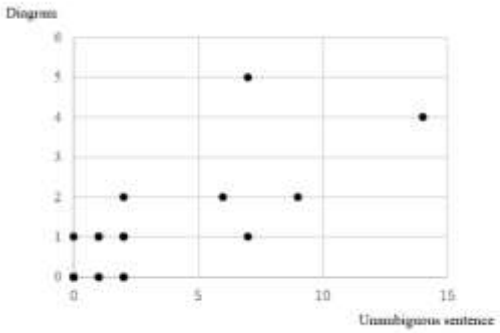

Figure 7 :Relation between unambiguous sentences and figures in terms

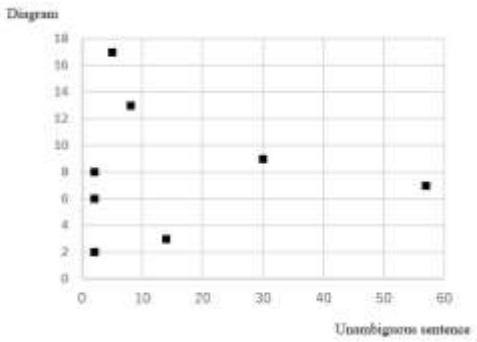

Figure 8 : Relation between unambiguous sentences and figures in sections

Table 7 : Correlation Coeficient

		Ambiguous sentences	**Unambiguous sentences**
Correlation coefficient	***term***	0.899	0.807
	section	0.840	-0.064

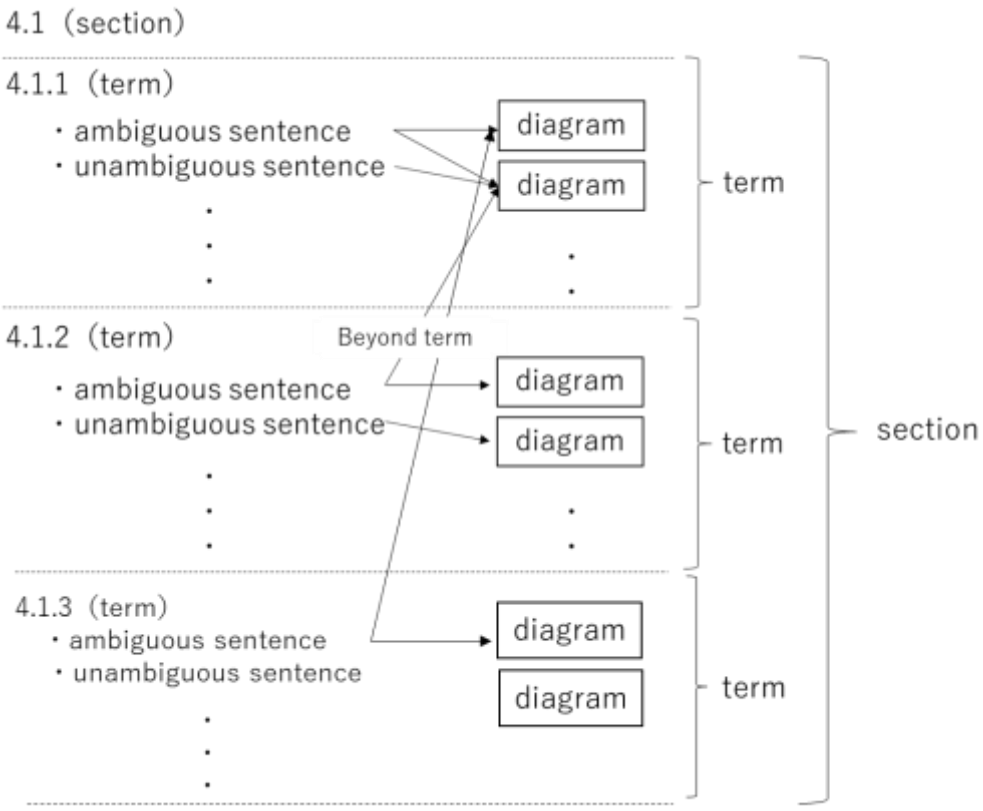

Figure 9 : Ambiguous sentences refer to diagrams across term

9 Conclusion and Further Work

In the face of massive retirement of experienced technicians, how to convey tacit knowledge to the next generation is a major issue. Not all can be solved by manualization. There is potentially tacit knowledge in what is recorded and documented. In this study, we thought that there was tacit knowledge in the part of the technical manual that the new engineer felt ambiguous. If ambiguous sentences can be identified mechanically, it will lead to discovery and extraction of tacit knowledge.

In the railway industry, where a large number of engineers are going to retire soon, several companies jointly have set up a maintenance manual creation working group. The Working Group has completed a 255-pages maintenance manual for bogie/wheelset. In this study, we identified the ambiguous sentences mechanically in 212 sentences of Chapter 4 describing the device. By applying SVM, which is a machine learning method, and selecting kernels and parameters appropriately, high discrimination performance was obtained. This confirms that the direction of the study is reasonable.

Moreover, we analyzed what kind of part of speech expresses ambiguity. Specifically, machine learning was applied by vectorization in which the target sentence was limited to specific parts of speech. In general, adjectives and adverbs are considered the primary causes of ambiguity. However, as a result of experiments, the same discrimination performance was obtained with nouns, particles and conjunctions other than verbs. It can be inferred that there are characteristic patterns representing ambiguity for each of nouns, adjectives, adverbs, particles and conjunctions. Although high discrimination performance was obtained in this paper, an easy to interpret pattern that characterizes ambiguous sentences was not obtained yet. In the future, we plan to examine what combination of parts of speech can characterize ambiguity.

In this paper, we focused on diagrams that are widely used in technical manuals. Therefore, in order to clarify the role and relation of tacit knowledge inheritance played by the diagrams often used in the manual, we analyzed the relation between the diagrams and sentences in the manual. As a result of the analysis, it was found that the related diagrams played a major role in the disambiguation of the sentences that two engineers determined ambiguous at least one of them. Moreover, it was found that not only the diagrams of the terms to which each ambiguous sentence belongs but also the diagrams of the preceding and following terms contributed to the disambiguation. Similarly, when it analyzed the relation between unambiguous sentences and diagrams, it was found that in the relation between unambiguous sentences and diagrams, charts that crossed the terms were not used. In addition, since there are multiple diagrams related to disambiguation, it is hypothesized that there is a correlation between ambiguous sentences and diagrams, and analyzed the relation between ambiguous sentences and diagrams. As a result, when comparing "sections" and "terms" that compose diagrams, differences were found in the relation between ambiguous sentences and diagrams, and in the relation between unambiguous sentences and diagrams. Focusing on the terms, it was found that there was a strong positive correlation in the relation between ambiguous sentences and diagrams, and in the relation between unambiguous sentences and diagrams, and no significant difference was found. However, focusing on the section, a strong positive correlation was found between the ambiguous sentence and the diagram, but no correlation was found between the un-ambiguous sentence and the diagram. This seems to be because the diagrams in Chapter 4 are widely involved in the resolution of ambiguity in the relation between ambiguous sentences and diagrams.

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