training (OJT) and training through mock-up plants. In addition to these methods, there is a simple, widely used method known as the 4-Round (4R) training method. This method helps trainees increase their hazard prediction capability by requiring them to identify and solve hazardous situations in illustrations depicting actual workplace hazards; moreover, they can discuss the solutions with an instructor and other trainees.

The problem is that the 4R method training requires only 30 - 60 minutes. The work site practice time is limited to 5 - 10 minutes, with the rationale that the full training time is too long [1][2]; however, this amount of training time is insufficient. In addition, the training is not adequate because at least one instructor is required for this type of 4R method training. Further, the training effect will decrease owing to a lack of variety in the training materials; this is caused by limited sharing of hazard sheets [3][4]. The 4R method is useful for teaching trainees to identify hazards, which can improve their hazard-prediction ability and develop their ability to implement countermeasures. However, the method's effectiveness is limited without a human instructor.

To address the 4R training system's requirement for human instructors, this paper proposes a training system based on the 4R training method. If our proposed training system is realized, trainees can use the system to train themselves anytime and anywhere.

This paper describes the proposed 4R method-based training system, and discusses a subsystem that uses machine learning to evaluate trainee answers.

2 Related works

The digital 4R training system aims to allow workers to train themselves anytime and anywhere using 4R training methods. We have studied 4R training systems [5][6]. The differences between conventional learning/training methods and the intentions of our research are described as follows.

There are various PC-based learning methods such as e-learning [7], ubiquitous learning [8], virtual reality (VR) [9][10], and augmented reality (AR) [11].

For example, VR provides a virtual environment built into a PC. VR training systems are designed to fill the gap between classroom learning and practice, and have been well studied [12][13]. The disadvantage of VR systems is the high cost of building virtual training environments. It is difficult to develop these training systems, because it is difficult to specifically determine the learning purpose. VR training is very useful for helping trainees to develop hazard-prediction capability, but it may not be useful for trainees with less experience.

We believe simple training that allows easy learning of essential hazards is more effective than VR training in the initial training stage. On the other hand, e-learning requires less time than VR training. In summary, e-learning is a training method that allows trainees to select answers from menu items on a PC-based learning system. This system type is mainly standalone or web-based. The disadvantage of e-learning systems based on a menu format is that the trainee can easily identify the answer, because it is displayed on the item menu. Therefore, our training method, which requires trainees to write their own answers, is superior to the conventional e-learning method, because it more accurately evaluates the hazard prediction ability of the trainee.

Round 3. Extraction of countermeasures

The trainees discuss countermeasures for the important hazards extracted in Round 2; an example is shown in Figure 3.

Figure 3: Round 3 Situation

Round 4. Sharing the agreed-upon countermeasure that the team will keep

Among the countermeasures that were identified during the Round 3 discussion, all trainees determine the most important countermeasure for the team to keep. With Japanese pointing and calling, the agreed-upon countermeasures are confirmed as the team goal. An example is shown in Figure 4.

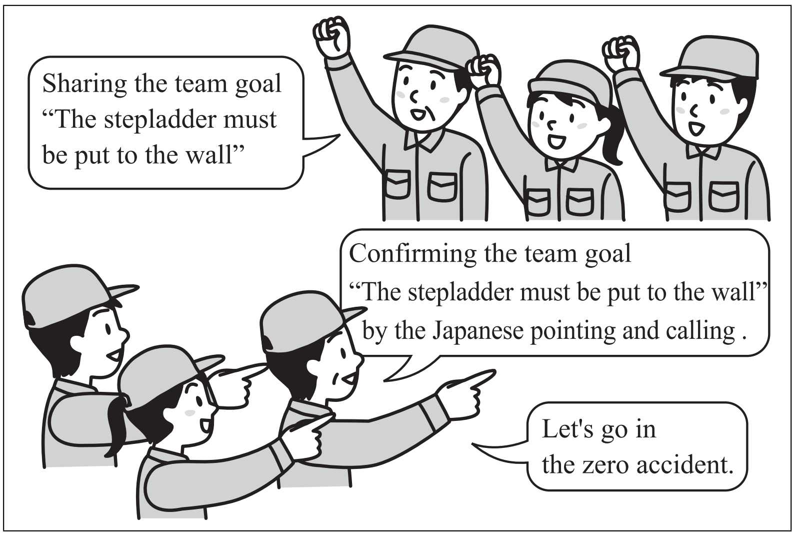

Figure 4: Round 4 Situation

4 Our proposed training system and research content

An image of our proposed training system is shown in Figure 5. Our PC-based training system plays the role of an instructor; thus, no human instructor is required. It provides a ubiquitous learning system that enables trainees to train themselves anytime and anywhere.

answers.

We decided to use the supervised machine learning method to analyze the processes that evaluate the trainee answer (Hereafter, supervised machine learning is referred to as machine learning). Machine learning is a technology that creates a computer that produces output according to input, by learning the relationship between the output and given input. The machine learning method creates a computer by learning inputted data tagged with positive and negative examples; based on this learning process, it can evaluate whether the trainee answers are correct. Thus, we performed an experiment to evaluate the learned machine created from the trainee answers, to evaluate whether the subsystem could be implemented in our training system. This evaluation employed the procedure described in following paragraph.

5 Evaluation experiment

This evaluation experiment aims to evaluate the accuracy of our subsystem, by evaluating the correctness of trainees' answers for hazard prediction training sheets.

5.1 Acquisition of the answer

The statements for generating and evaluating learning machines were gathered from 43 high school students. The statements contained answers provided by students during the 2nd round of 4R method training, and were written in Japanese. Fourteen training sheets were used in this evaluation: Nos. 1, 4, 5, 10, 12, 13, and 14 from the book [14] and Nos. 3, 11, 16, 17, 18, 19, and 20 from the book [15]; these sheets were also written in Japanese. These sheets were selected because they were relatively easy for the students to understand. Each group consisted of two students, who answered 10 answer statements per training sheet. Therefore, approximately 40 answers were gathered per sheet. The authors added class tags indicating positive or negative examples of each answer statement provided by the students. Coincidentally, the numbers of positive and negative examples were approximately the same.

5.2 Creating the subsystem

The learned machines used by the trainee answer evaluation subsystem [5.1] were created using the following procedure.

Step 1. Extraction of morphemes from answers

Morphemes were extracted from the trainee answers [5.1]. A morpheme is a minimum unit word based on a part of speech. The tool used to extract the morphemes was MeCab [16].

Step 2. Elimination of extremely frequent morphemes

Extremely low/high frequency morphemes were eliminated from the morphemes extracted in Step 1., according to a limitation parameter.

Step 3. Creating word vectors

Word vectors were created based on the selected morphemes that were processed in Step 2.. A vector is generally referred to as a "bag-of-words."

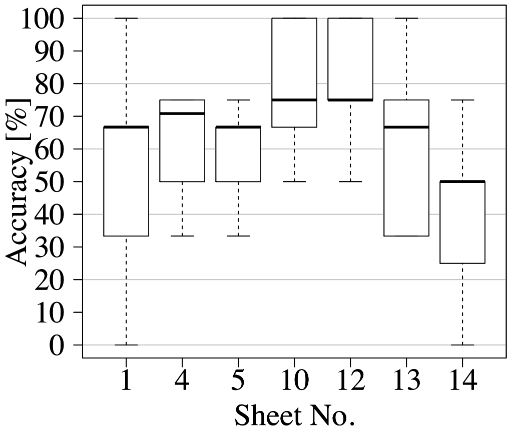

Figure 7: Result of 10-CV for the sheet [14]

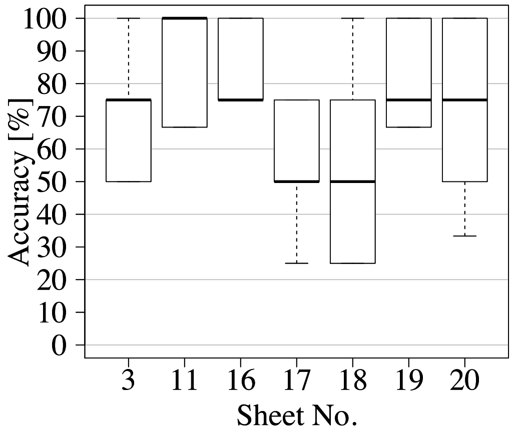

Figure 8: Result of 10-CV for the sheet [15]

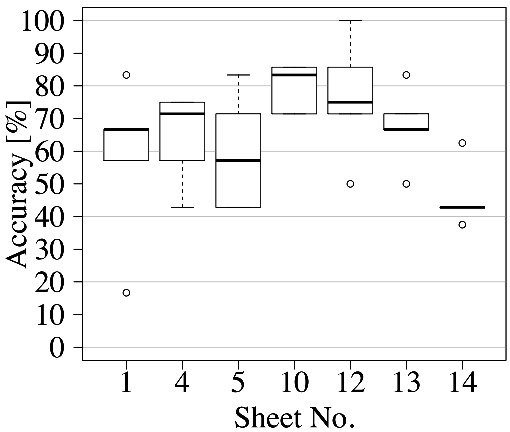

Figure 9: Result of 5-CV for the sheet [14]

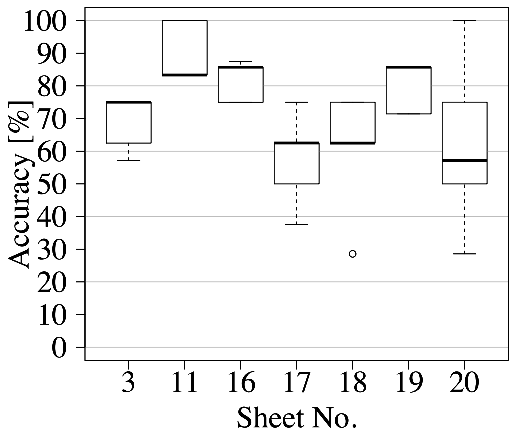

Figure 10: Result of 5-CV for the sheet [15]

can be used to implement our training system. The results produced by the 5-CV are shown in Tables 1 and 2.

Table 1: 5-cross validations for sheet book [14]

Sheet No.	1	4	5	10	12	13	14	Mean
Mean [%]	58	64	60	80	76	68	46	64
Std. [%]	22	13	16	7	17	11	9	14

The graphs in Figures 9 and 10 show the average (”Mean”) and the standard deviation (”Std.”) of the accuracy, which was calculated from the results evaluated by the 5-CV for each sheet. Each table shows that an accuracy rate of over 70% was produced for two sheets, and an accuracy rate of over 80% was produced for one sheet in the traffic collection [14]; An accuracy rate of over 70% was produced for three sheets, and an accuracy rate of over 80% was produced for three sheets in the ready-to-use sheet collection [15]. In total, we calculated an accuracy (precision) rate of over 70% in approximately 36% (=5/14) of the sheets, and an accuracy rate of over 80% in 29%(=4/14) of the sheets.

If this subsystem is implemented in the proposed training system, the required accu-

Table 2: 5-cross validations for sheet book [15]

Sheet No.	3	11	16	17	18	19	20	Mean
Mean [%]	69	90	82	58	61	80	62	72
Std. [%]	8	8	6	13	17	7	24	12

racy should be greater than 80%, because the number of correct trainee answers flagged as incorrect by the subsystem should be reduced.

6 Conclusion

We proposed a 4R training system and a machine learning-based evaluation method to determine whether trainee answers are correct or incorrect. This paper described a method to create a learning machine as a subsystem, and the results of an evaluation experiment against a textbook [14] using SVM. The experimental results an showed the accuracy rate (precision) for two sheets were 64 ± 14[%] and 70 ± 12[%]. The result indicates that the current accuracy is not yet sufficient for hazard prediction training. However, an accuracy rate of over 70% was produced for some sheets, which indicates the possibility of realizing our proposed hazard prediction system.

In future works, we aim to conduct additional research to improve the system's accuracy, by improving methods to create training data and implementing assistance mechanisms (such as a hint function). With these improvements, it is possible that the proposed 4R training system could become a practical application.

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