

Research Article

Skill Model Estimation of Ability for Reading Drawings

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ABSTRACT

In Japan, students study various ways of understanding 3D drawings in junior high school-level technical education, high school-level industrial education, and university-level engineering education. However, without an understanding of trigonometry, reading the drawings is difficult. Moreover, drawing the assembly parts is equally difficult. To address these concerns, many research studies have been conducted. These examinations have used before–after analysis, but none has used time-series data analysis. Therefore, this study aims to develop a new quantitative evaluation method of 3D recognition ability through the use of time-series analysis.

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1. INTRODUCTION

In Japan, teaching engineering drafting is conducted in junior high schools, industrial education of high schools, industrial colleges of technology, and engineering departments of universities as a component of technical education. If students cannot understand trigonometry handled in engineering drawing, they cannot read or draw drawings. Because of this need, many efforts to improve reading and drawing skills are made. However, these efforts were carried out with only a before-and-after evaluation, not with one that handles the learning curve (time series evaluation).

In order to acquire skills effectively under a teacher's guidance, proper support through modeling of learning is important. If it is possible to evaluate the learning process from initial learning performance, it is equally possible to evaluate the learning support that an individual receives. One of the authors proposed a method to regard the skill acquisition process in the model between teacher and student as a “first-order + time delay” system based on the control engineering approach [1]. However, in past studies to evaluate the learning process, power functions or exponential functions are used as learning curves.

Therefore, we propose a new method to evaluate students' skills in engineering drawings.

2. PROPOSED READING SKILL MODEL

The learning curve for skill evaluation is typically represented by Equations (1) and (2), one involving a power function and the other involving an exponential function.

The power function is following equation.

$$T_R = a + bN^{-c} \quad (1)$$

where T_R denotes the response time, a denotes the asymptotic value, b denotes the difference between initial and asymptotic performance, N denotes the number of trials, and c denotes the learning rate parameter.

The following equation expresses the exponential function.

$$T_R = a + be^{-cN} \quad (2)$$

where a again denotes the asymptotic value, b denotes the amount that learning can reduce T_R , c denotes the rate at which asymptotic level performance is approached as a proportion, and N again denotes the number of trials.

We used Equation (2) for evaluating the reading skill of engineering drawings. However, in order to evaluate skill based on the real learning time rather than the amount of learning (practice), we proposed following Equation (3) by changing from N to real time R_T (total learning time) in Equation (2).

$$T_R[n] = a + be^{-cR_T[n]} \quad (3)$$

where the relationship between T_R and R_T when the amount of learning is n is as follows [Equation (4)].

$$R_T[n] = \sum_{i=1}^n T_R[i] \quad (4)$$

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3. SKILL MODEL PARAMETERS ESTIMATION USING A REAL-CODED GENETIC ALGORITHM

The parameters of skill model a , b , and c are arranged as cells included in a string. These parameters included in the string are given by real values. The real-coded GA is used, which is explained as follows:

(i) Initialization

The generation number G is set, and the initial individuals are produced with random real-codes within the initial domain which is set in advance. Here, the number of population is set as N_p .

(ii) Selection

The fitness value $f(l)$ is calculated by the following Equation (5).

$$f(l) = \frac{1}{1 + \sum_{k=1}^n \{\hat{T}_R(k) - T_R(k)\}^2} \quad (5)$$

where \hat{T}_R and T_R respectively denote the learning time and the estimated learning time by the parameters of skill evaluation model a , b , and c . Each individual P_i is arranged in order, based on the fitness value. Then, α percent individuals with superior fitness values are selected, and saved in the next generation.

(iii) Crossover

The $(100 - \alpha)$ percent remaining are generated by the crossover. Two individuals, P_a and P_b are chosen from among the superior α percent, and new individuals P_c and P_d are generated by using the following procedure:

$$P_c(i) = P_{\text{sup}}(i) - \frac{|P_a(i) - P_b(i)|}{4}, \quad (6)$$

$$P_d(i) = P_{\text{sup}}(i) + \frac{|P_a(i) - P_b(i)|}{4} \quad (7)$$

where P_{sup} in Equations (6) and (7) refers to the individual with the superior fitness value, i.e., P_a and P_b . Note that this procedure is used for every cell included in P_a and P_b .

(iv) Mutation

Of all individuals who are randomly selected and given by the crossover, β percent are chosen and replaced with randomly determined values within the initial domain.

(v) Update

The procedure from (i) through (iv) is repeated for generations. This procedure is summarized in Figure 1.

Initial individual population

P_1 [a b c]
 P_2 [a b c]
 P_3 [a b c]
 P_4 [a b c]
 \vdots
 P_{N_p} [a b c]

Selection

P_1 [a b c]
 P_2 [a b c]
 P_3 [a b c]
 P_4 [a b c]
 \vdots
 P_{N_p} [a b c]

fitness function

$f(P)$

0.9 high

0.5

0.4 next generation

0.2

0.1 low

Crossover

parents

P_a

P_b

children

P_c

P_d

Mutation

P_i^{mut} [a b c]

β percent cells are replaced with random values.

Figure 1 | Schematic figure of GA flow chart.

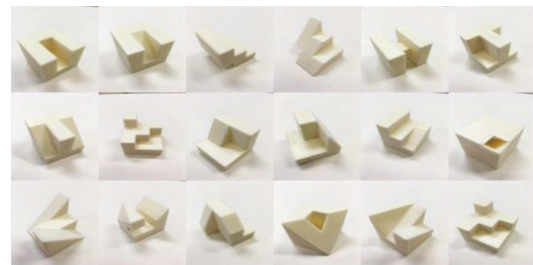


Figure 2 | 3D models of 30 mm square.

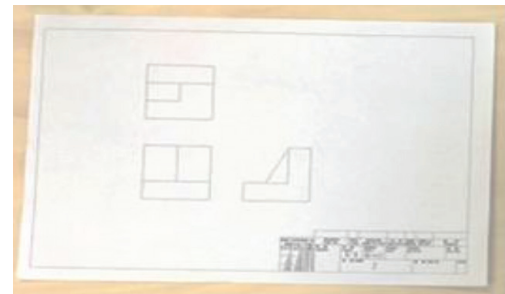


Figure 3 | Drawing of 3D model.

4. EVALUATION OF PROPOSED READING DRAWINGS SKILL MODEL

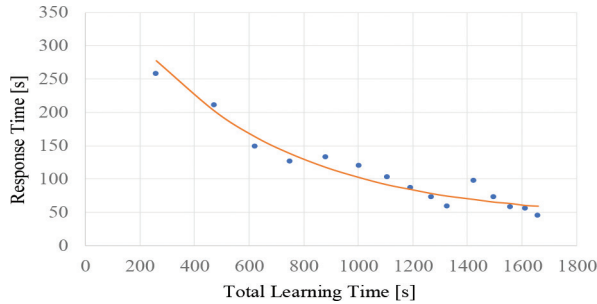
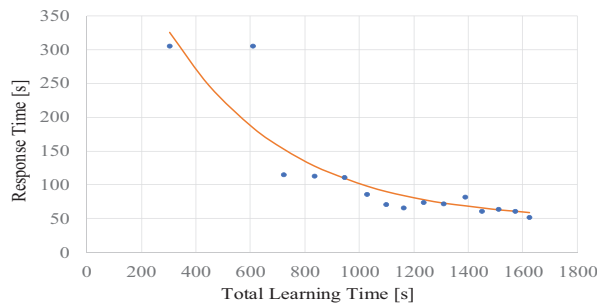
The effectiveness of the proposed reading drawings skill model was evaluated from the relationship between the learning time and the reading time (response time) of drawing. Two university students who learned the basics of engineering drawing were the research participants.

The procedure of the experiment is explained as follows.

- (1) Eighteen kinds of 3D models of 30 mm square shown in Figure 2 and drawings by third angle projection method shown in Figure 3 are prepared.

Table 1 | The total learning time and the response time of participants

A	R_T	259	212	150	127	133	121	103	87	74	60	98	73	59	56	46
	T_R	259	471	621	748	881	1002	1105	1192	1266	1326	1424	1497	1556	1612	1658
B	R_T	305	305	114	112	110	85	70	65	73	71	81	60	63	60	51
	T_R	305	610	724	836	946	1031	1101	1166	1239	1310	1391	1451	1514	1574	1625

**Figure 4** | Learning curve of A.**Figure 5** | Learning curve of B.

- (2) The participants randomly showed the drawing, and worked to match the three-dimensional model and the drawing. At this time, the time (response time) required for matching work was measured.

The procedure from (1) through (2) was repeated for 15 times.

The total learning time R_T and the response time T_R of participants (A and B) measured by experiment are shown in Table 1. Figures 4 and 5 are graphs of Table 1. In these graphs, total learning time R_T and response time T_R , the red lines in Figures 4 and 5, were estimated the reading skill model by using the real-coded GA. Then, estimated parameters (a , b , and c) were showed in Table 2.

It is clear that the estimated read skill models of A (Figure 4) and B (Figure 5) fit almost to the response time. Furthermore, the reading skills of A and B can be understood from the parameters of Table 2. Specifically, although A has a shorter response

Table 2 | The parameters of drawing skill model

	a	b	c
A	40	379	0.0018
B	46	566	0.0023

time than B, the response times of A and B are almost equal. This shows that B has a higher learning rate than A. From the above, it was found that the proposed reading skill model suggested individual characteristics.

5. CONCLUSION

We proposed a model to evaluate the reading skills of 3D drawings and verified its effectiveness. Specifically, the reading ability of two participants was evaluated individually using the proposed skill model. In the future, we plan to develop a learning support system using this reading skill model.

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