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Attempt to Evaluate Pictogram Complexity Using Fractal Dimension

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ABSTRACT

Pictograms are used in a variety of situations, including road signs, public facilities such as train stations and airports, evacuation guidance during disasters, and icons on computer screens. Pictograms must be easy to understand, so that people can immediately understand what they mean, but some pictograms are difficult to understand. We assume that there are many factors that contribute to the understandability of a pictogram, one of which is the complexity of the pictures in the pictogram. We also assume that the complexity of the pictogram affects the length of time it takes to understand the pictogram. We investigated the relationship between the fractal dimension of a pictogram and the time it takes to understand the pictogram. We found no correlation between the fractal dimension of a pictogram and time taken to understand it. We also found no correlation between the fractal dimension of a pictogram and percentage of correct answers to what the pictogram indicated.

Keywords: Pictogram, Fractal dimension, Complexity

INTRODUCTION

A pictogram is a simplified visual symbol that conveys information without words. In Japan, pictograms were first used at the 1964 Tokyo Olympics. At that time, most Japanese people still had difficulty communicating in foreign languages. Therefore, a visual device was needed to help both Japanese and foreign visitors understand the facilities and equipment (Yukio, 1995).

Pictograms are effective in communicating information to foreign tourists who cannot read Japanese. However, if a large amount of information is conveyed in a single pictogram, the pictogram is likely to be complex, making it difficult or time-consuming to understand it. It would be helpful to quantitatively assess the complexity of a pictogram and determine a threshold of pictogram complexity, which is necessary for rapid understanding of pictograms.

A fractal is a measure of random complexity in nature (Benoît, 1982), and a fractal dimension is a quantified measure of fractal self-similarity features and used as a measure of the degree of complexity. The more complex the object being evaluated, the larger the fractal dimension.

There have been many studies that have attempted to quantify image complexity in fractal dimension. One study examined the extent to which fractal dimension can explain judgments of perceived beauty (Forsythe, 2011). Measures of fractal dimension explained more of the variance in judgments of perceived beauty in visual art than measures of visual complexity alone, especially in abstract and natural images. Another study attempted to quantify the complexity of leaf shape in fractal dimension (John, 1995). Their experimental results indicated that fractal dimension provides a useful quantitative measure of the elaboration of shape complexity during plant development. Ota et al. examined the relationship between line length and stroke length of Chinese characters (Japanese Kanji) (Morihiro, 2019). They used fractal dimension to show that the shape of a Chinese character can be said to become plane-fillingly complex as the number of strokes increases. However, few studies have examined pictogram complexity using fractal dimension.

We attempted to examine the relationship between the fractal dimension of a pictogram and time taken to understand that pictogram to determine if it is a valid indicator of pictogram complexity.

Evaluation Method and Results

Kosaka et al. conducted an experiment in which 13 participants read 56 pictograms and answered what each pictogram was (Tatsuya, 2023). In this study, we selected 22 of the 56 pictograms for our evaluation. Figure 1 shows the 22 pictograms, and Table 1 shows the time taken to answer each question, i.e. the time to understand each pictogram. The number of pictograms from P1 to P22 in Table 1 are defined in Figure 1. Table 2 shows the average percentages of correct answers to what the pictogram indicated.

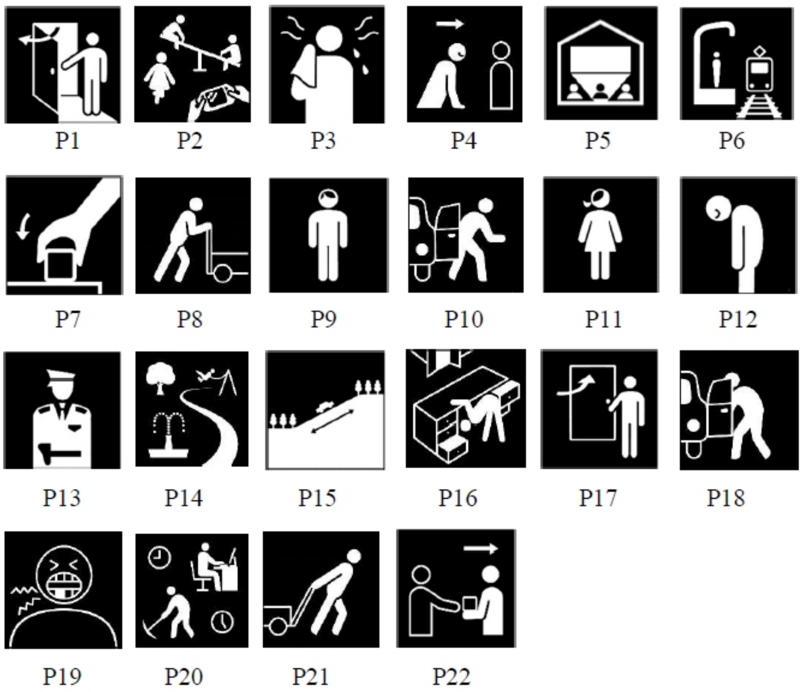

Figure 1: Pictogram evaluated in this study.

Table 1. Average time to understand pictogram.

Pictogram	Time to Understand [s]	Pictogram	Time to Understand [s]
P1	3.94	P12	3.21
P2	2.74	P13	2.34
P3	2.34	P14	2.34
P4	5.78	P15	3.15
P5	7.12	P16	2.34
P6	1.78	P17	2.93
P7	1.92	P18	3.44
P8	2.42	P19	1.86
P9	3.13	P20	3.41
P10	2.06	P21	3.18
P11	1.65	P22	2.80

Table 2. Average percentage of correct answers.

Pictogram	Percentage of Correct Answer [%]	Pictogram	Percentage of Correct Answer [%]
P1	42	P12	58
P2	100	P13	75
P3	83	P14	100
P4	8	P15	75
P5	92	P16	92
P6	50	P17	75
P7	42	P18	33
P8	83	P19	8
P9	8	P20	17
P10	100	P21	75
P11	67	P22	8

Fractal dimensions were calculated for the 22 pictograms by using box counting. The size of each pictogram was 450 dots square. Table 3 shows the results of the calculation.

Figure 2 shows the relationship between time to understand shown in Table 1 and fractal dimension shown in Table 3. The correlation coefficient between fractal dimension and time to understand was −0.275. Figure 2 and this correlation coefficient indicate that there is no linear relationship between the fractal dimension and time to understand.

Figure 3 shows the relationship between percentage of correct answers shown in Table 2 and fractal dimension shown in Table 3. The correlation coefficient between fractal dimension and percentage of correct answers was −0.326. Figure 3 and this correlation coefficient indicate that there is no linear relationship between the fractal dimension and percentage of correct answers.

Table 3. Fractal dimension.

Pictogram	Fractal Dimension	Pictogram	Fractal Dimension
P1	1.912	P12	1.949
P2	1.937	P13	1.934
P3	1.924	P14	1.941
P4	1.954	P15	1.889
P5	1.907	P16	1.927
P6	1.936	P17	1.953
P7	1.930	P18	1.940
P8	1.953	P19	1.964
P9	1.952	P20	1.946
P10	1.934	P21	1.948
P11	1.954	P22	1.930

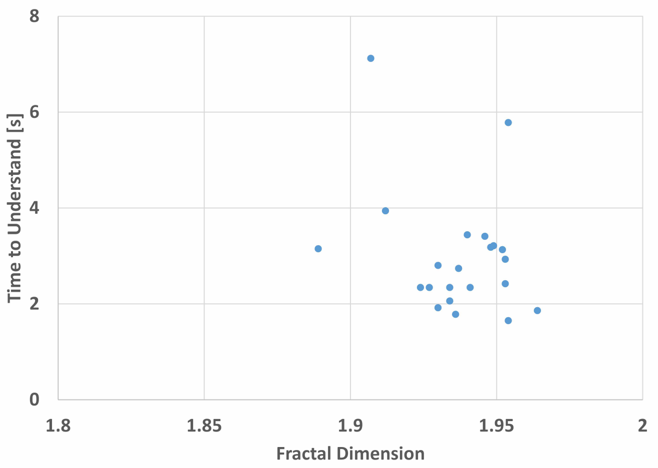

Figure 2: Relationship between fractal dimension and time to understand.

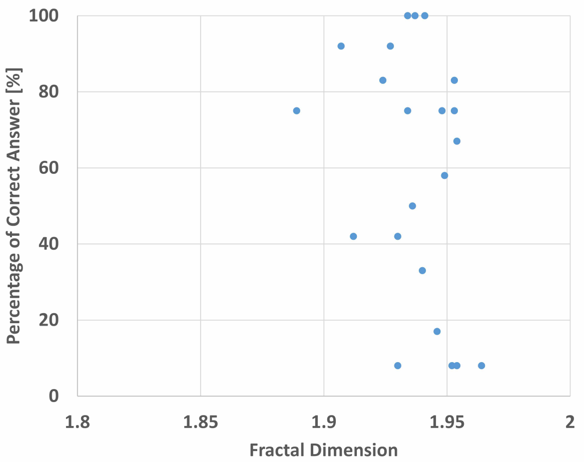

Figure 3: Relationship between fractal dimension and percentage of correct answer.

Kazuya et al. proposed a method for accurately calculating the fractal dimension in box counting (Kazuya, 1997). The resolution of the image and size of the box set by box counting are factors that affect the accuracy of fractal-dimension calculation. If these values are too large or too small, the accuracy of the fractal- dimension calculation will be low. Kazuya et al. therefore proposed setting upper and lower bounds for these values so that they exist in the correct range when calculating the fractal dimension. They called these upper and lower limits the cutoff levels (Kazuya, 1997). The lower cutoff level should be set to a cell value that is at least greater than the resolution and observation accuracy of the figure. The upper cutoff level should not depend on the section where all cells contain figures or where the data show variation.

Therefore, we recalculated the fractal dimension shown in Table 3 with set cutoff levels. We set the lower cutoff level to 1/450 and upper cutoff level to 1/30. Table 4 lists the results of the recalculation.

Figure 4 shows the relationship between time to understand shown in Table 1 and recalculated fractal dimension shown in Table 4. The correlation coefficient between recalculated fractal dimension and time to understand was −0.316. Figure 4 and this correlation coefficient indicate that there is no linear relationship between recalculated fractal dimension and time to understand.

Figure 5 shows the relationship between percentage of correct answers shown in Table 2 and recalculated fractal dimension shown in Table 4. The correlation coefficient between recalculated fractal dimension and percentage of correct answers was −0.324. Figure 5 and this correlation coefficient indicate that there is no linear relationship between recalculated fractal dimension and percentage of correct answers.

Table 4. Recalculated fractal dimension.

Pictogram	Fractal dimension	Pictogram	Fractal dimension
P1	1.934	P12	1.976
P2	1.943	P13	1.960
P3	1.957	P14	1.957
P4	1.967	P15	1.938
P5	1.925	P16	1.93
P6	1.952	P17	1.961
P7	1.951	P18	1.954
P8	1.963	P19	1.957
P9	1.973	P20	1.951
P10	1.952	P21	1.959
P11	1.974	P22	1.956

We could not find any correlation between the fractal dimension of a pictogram and time taken to understand it. We also could not find any correlation between the fractal dimension of a pictogram and percentage of correct answers to what the pictogram indicated. We consider this is because that the complexity that humans perceive when looking at a pictogram does not necessarily correspond to the complexity indicated by the fractal dimension. Why this difference occurs should be investigated. We also believe it is necessary to investigate the relationship of the fractal dimension of pictograms to other indexes of pictogram-reading time and pictogram correctness.

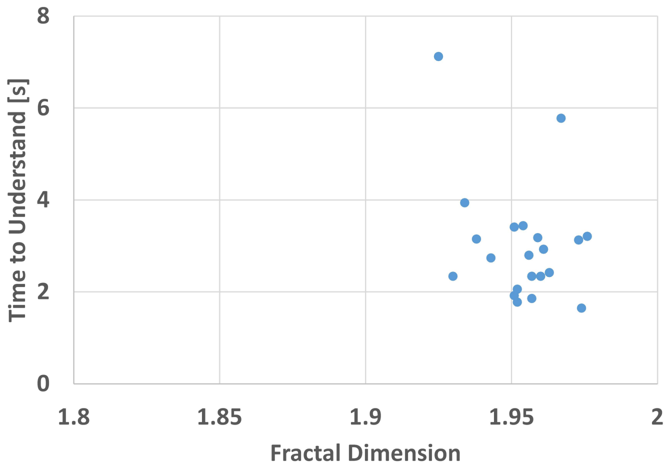

Figure 4: Relationship between recalculated fractal dimension and time to understand.

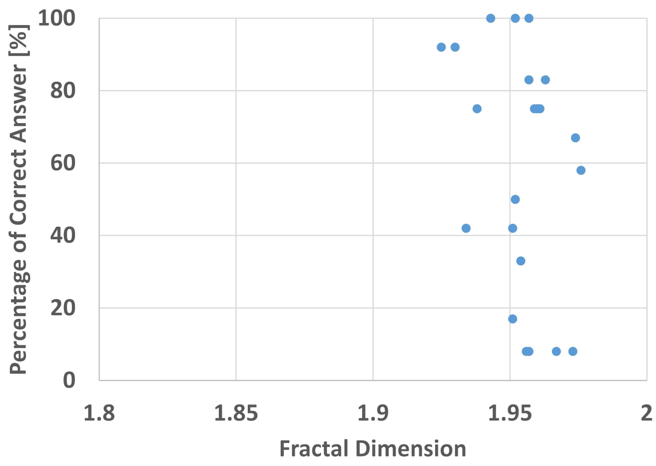

Figure 5: Relationship between recalculated fractal dimension and percentage of correct answer.

CONCLUSION

We assumed that the fractal dimension of a pictogram is one of indexes that represents the complexity humans perceive when they see a pictogram. We also assumed that the more complex the pictogram, the longer it would take to understand. We assumed a monotonically increasing relationship between the fractal dimension of a pictogram and time it takes to understand the pictogram and investigated the relationship between the two.

The results indicate no correlation between the fractal dimension of a pictogram and time to understand the pictogram. We then investigated the relationship between the percentage of correct answers regarding the meaning of a pictogram and the fractal dimension of that pictogram but found no correlation between the two. Finally, we recalculated the fractal dimension with cutoff levels to increase the accuracy of the calculation and examined the relationship with the time to understand and found no correlation between the two.

We assume that compared to kanji, pictograms are understood much differently by people, and this difference caused one of the reasons why the correlations mentioned above did not occur. It is required to examine the relationship between the subjective rating of human complexity for pictograms and the value of fractal dimension. We also assume that the value of fractal dimension does not necessarily correspond to an assessment of subjective pictogram complexity. In order to create an index of human perceived complexity for a pictogram, it is considered necessary to make some correction when calculating the fractal dimension. For example, it is possible to calculate the fractal dimension of an image in which only the contour of the pictogram is extracted.

Future work includes examining the relationship between other indexes and fractal dimension, for example, investigating the relationship between a person's gazing position when looking at a pictogram and the fractal order of that position. We will also calculate the fractal dimensions of other pictograms to investigate the characteristics of fractal dimension in pictograms.

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