Characteristics Analysis of Architectural Configuration Using Modified Box-count Method

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***Abstract* — A floor plan in architecture includes elements that determine circulations of a person who experiences the space of the architecture and that is considered to play an important role in the connection between the person and the architecture. Especially since modern times, various shapes that deviate and escape from a floor plan by means of right-angled constitution have arisen and have been used as elements of architecture. Therefore, it is necessary to consider "a floor plan".**

In this paper, we propose an index that is able to classify various floor plans in architecture from the person's view. We analyze floor plans of architecture by means of a proposed "modified box-count method". We compare the results and make consideration.

Ⅰ. INTRODUCTION

In the field of design, the shape resulting from a plastic formation is generally called "configuration". In other words, a configuration is the embodied existence of an abstract idea that can be grasped by the senses of sight and touch. Because architecture is, of course, an artistic activities, it is possible to attempt certain interpretations of architecture from a configurational aspect. However, unlike product designs, etc., because architectural structures have a certain reason for being when they are solidly and spatially significant, both the internal and external architectural configurations become objects of aesthetic evaluation. Further, the impression of the architectural configuration varies with distance from the viewer in every aspect, ranging from the façade proportions to the feel of the walls for aesthetic evaluation. It can be said that architectural structures are objects very difficult to deal with from a configurational point of view.

Accordingly, in this study we limit our theme to the analysis of only architectural floor plans and make an attempt to create an index as an aid in grasping the characteristics of floor plans.

Ⅱ. PROCESS OF CREATING THE INDEX

A. Non-rectangular configuration

If trying to deal with configurations in absolute theory, since everything has its own configuration, the number of possible configurations approaches infinity. According to this study, we try to limit our evaluation of objective configurations to some extent by paying attention to whether those objective configurations can be formed into rectangular structures or not.

Since a rectangular structure using straight lines creates an intellectual, inflexible, and clear impression, this type of formation has been used very widely to-date as a standard architectural configuration[1]. The simplicity of this type of formation gives, however, too monotonous of an impression, and psychologically has a risk of causing the person viewing the object to feel tired of the formation. Modern architects, therefore, have made efforts to eliminate tiring impressions as much as possible by adding spherical space, diagonal and distorted wall surfaces, etc. to the architecture for accent. It can be said that if these accented architectural configurations are called non-rectangular formations, the non-rectangular formations have indeed eliminated the tiresome impressions brought about by traditional rectangular formations.

Refreshing discoveries by the five human senses, such as the visual sense often allow us to appeal to the emotion of "surprise". It can be said that the diagonal or distorted surfaces of walls which appear suddenly in an architectural configuration consisting of a repetition of monotonous square plans give just such an architectural surprise to the viewer. Giving such a surprise aims at eliminating the tiresome feeling.

Considering such features of architectural surprise to be common to all the configurations designed by non-rectangular formation, if the degree of the surprise can be quantified by any means, the quantified result can become an index indicating an aspect of the configurational characteristics of the object.

B. Similarities between the degree of the surprise and the fractal theory

Now, how should the degree of the surprise be measured? In the preceding paragraph Ⅱ-A, the presence of the walls having diagonal or distorted surfaces that appear suddenly in a repetition of monotonous square plans was taken as an example of the degree of surprise. Namely, when a tired visual feeling brought about by a repetition of monotonous square plans is eliminated temporarily, by an architectural material having a nature different from that of the monotonous square plans. The viewer who experiences the architectural space is hit by a sense of surprise. Even an architectural structure consisting of only a single space can give the viewer a visual sense of surprise by having changes in each part of the architectural space. Further, it is also an important fact that the viewer who experiences an architectural space is an existence moving about freely within the architectural space making contact with the space at all possible distance. In other words, there are all sorts of non-rectangular architectural configurations ranging from ones having only a single part accented differently to others having a variety of accents at every part at all possible scales. It may be true that the degree of surprise the viewer experiencing from the latter space configuration would perhaps be much greater than that of the former space configuration.

Now, we notice that the considerations stated so far with respect to the degree of surprise that one experiences from an architectural space configuration is similar to the concept of the fractal and the way of considering the fractal dimension. The Mandelbrot set brings about a great variety of scenes dependent on the position of observation or changes in scale. The same is true of trees, coastlines, etc. existing in the natural world. Moreover, the fractal dimension makes it possible to quantify such natural complexities, the magnitudes of changes, and so on.

That is, it can be considered that the method for measuring the fractal dimension representing the complexity an object having a fractal nature is also applicable for measuring the degree of surprise with respect to space configurations.

Ⅲ. PROPOSED METHOD

A. Modified Box-count method

There are many evaluation types available for measuring the fractal dimension, i.e., the similarity dimension, the Hausdorff dimension, the spectrum dimension, etc.[2]. In this study, we paid attention to the capacity dimension which has been used frequently to analyze existing architectural space configurations. The capacity dimension is defined based on covers using the constituents having the same size and shape, (A square is actually used for the constituent which is hereinafter called "box")(the box-count method). Out of a group of boxes covering an objective configuration, only some of those containing the objective configuration are extracted and are used as the object for the measurement of the fractal dimension at the next stage. The procedure for measuring the fractal dimension of the objective configuration by means of the capacity dimension is enumerated in sequence as follows.

1) Calculate the total number of boxes extracted from the objective configuration. Further, change the scale of the boxes and then do the same work, that is, calculate the total number of boxes extracted from the objective configuration.

2) Plot the data obtained from step 1) together with the inverse of the changed scale of the extracted boxes on a full logarithmic table.

3) Calculate the inclination of the straight recurrent line obtained from the full logarithmic table prepared at step 2).

According to the conventional box-count method, all the boxes containing the objective configuration are extracted. However, in a new method for extracting the boxes that we propose in this study, a number of additional steps are required. Therefore, the condition for extracting the boxes according to the modified box-count method used in this study are described in the following paragraph Ⅲ-B.

B. The new method for extracting the boxes

The procedure in the new method for extracting the boxes used in this study is enumerated in sequence as follows. In addition, for an extraction sample, refer to Fig. 1 (steps a through d in Fig. 1 correspond to the following description steps a) through d), respectively.

a) Cover the objective configuration with a group of boxes having a certain size.

b) Extract the boxes containing the objective configuration.

c) Out of the group of boxes obtained by above step b), extract only the boxes inside or outside the configuration.

d) Out of the group of boxes obtained by step c), extract only the box groups which consist of two or more boxes connected in diagonal directions.

The total number of the boxes that remain after the completion of the above steps becomes the data obtained in the preceding paragraph 2). Namely, the above steps c) and d) are the new procedural steps added to the procedure of the conventional box extraction method.

Moreover, a little more explanation needs to be added to the operation c).

Representing the objective configuration with lines, because the configuration is generally closed, two areas definitely appear inside and outside the configuration. If the boxes containing the configuration are extracted leaving such a state that there are two areas inside and outside the configuration as it is, the extracted boxes may present the threat of duplication inside and outside of the configuration. In that case, it is necessary to select either the inside boxes or the outside boxes. In addition, if the configuration to be analyzed is a picture or sculpture, the index for grasping its features can be measured easily.

The above procedure is the new method proposed in this study for measuring the features of a configuration, and is called the modified box-count method[3].

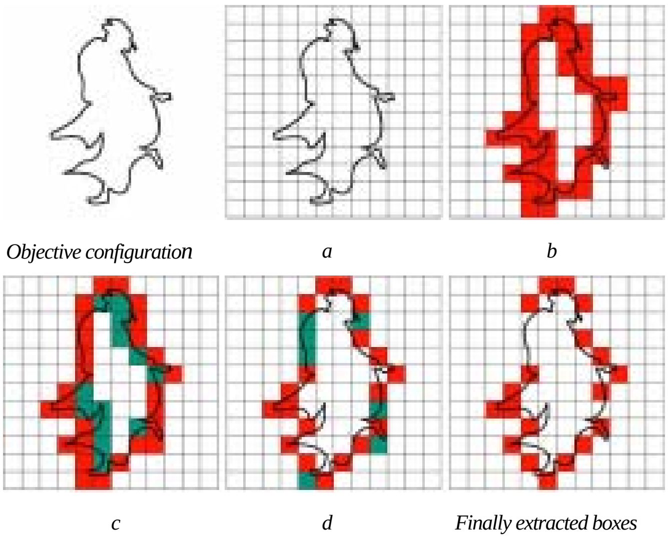


Fig. 1 Procedures for extracting the boxes

(Red boxes: Extracted boxes. Green boxes: Deleted boxes.)

Ⅳ. APPLICATION OF THE MODIFIED BOX-COUNT METHOD TO ARCHITECTURES

A. Outline

Based on the modified box-count method for extracting and calculating the boxes for a configuration described in the preceding chapter, the application of this method to architectures is described in this chapter.

B. Method of the application

(a) Setting up an area for extracting the boxes

As stated to a certain extent in paragraph Ⅲ-B, there is some difference in the method for extracting boxes for picture or sculpture configuration versus architectural configuration. The difference is mainly that an architectural configuration has an inside. In other words, if the object is an architectural configuration, consideration of the area for extracting boxes mentioned at work step c) in paragraph Ⅲ-B from either inside or outside the configuration is a decision entrusted to the user. That is, if the purpose of the analysis is the internal space of the architecture, the inside may be selected, whereas if the purpose is the external space, the outside may be selected. In this connection, since attention in this study is paid not to the whole body of an architectural configuration, but to its internal space (view point of a person experiencing the space), the inside area should be selected.

(b) Division of the components of floor plan configuration

It was described in Chapter Ⅱ in this thesis that paying attention to whether or not an objective floor plan is formed into a rectangular structure using straight lines is an assumption for creating a relevant index. In order to clarify the type of architectural structure such as rectangular type or non-rectangular type, various components constituting an architectural structure need to be defined and divided clearly. Otherwise, the architectural structure's components cannot be clarified. The aforementioned matter is also a difference between the sculptural configurations and the architectural configurations. In this paragraph, we want to consider this difference.

The architectural component that affects architectural floor plans is the most probably "walls". Looking at a floor plan as a single unit of configuration, the thing that gives the first impression to us would perhaps be the overall shape of the configuration. At the same time, the presence of the lines running lengthwise and crosswise throughout the inside of the configuration can also be an example of what impresses us about the overall configuration. It can be said from these impressions that the wall as a component of a configuration has not only one aspect of merely composing the configuration as a part of the architectural floor plan as its name shows, but also the other aspect of playing a role in affecting the sensations of the person experiencing the architectural space as an independent individual.

Therefore, in this study, we consider the walls as existing independently, and we deleted each of the boxes containing parts where two or more lines cross each other or are contained (Fig. 2).

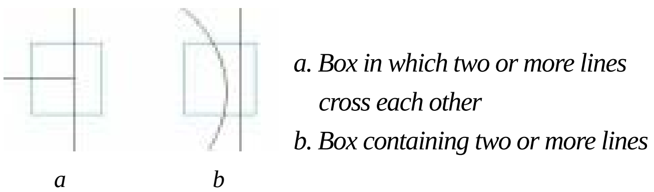


Fig. 2 Example of boxes to be newly deleted

(c) Procedure for working on the modified box-count method

The following defines the procedure for working on the modified box-count method necessary when the method is applied to architectural floor plans, and additionally attempt to examine all the items appearing in the preceding paragraphs.

1) Extract boxes from the objective configuration in accordance with the procedure shown in the following steps a) through e).

a) Cover the objective configuration with a group of boxes having a certain size.

b) Extract the boxes containing the configuration.

c) Out of the boxes extracted at sub-step b), delete each of the boxes which contain a configuration in which two or more lines cross each other and are contained.

d) Out of the boxes extracted at sub-step c), extract only the inside boxes.

e) Out of the boxes extracted at sub-step d), extract only the part where two or more boxes are connected in a diagonal directions.

2) Calculate the total number of boxes extracted at step 1). Further, after changing the scale of the boxes, carry out the same work as step 1).

3) Plot data obtained at step 2) above together with the scale inverse to that of the boxes on a full logarithmic table.

4) Calculate the inclination of the straight recurrence line obtained from the full logarithmic table prepared at step 3).

In addition, the change of the box scale done at step 2) means a change in the relative distance between the person experiencing the space and the space itself. In this article, we use four types of boxes having scales of 2m x 2m, 1m x 1m, 50cm x 50cm, and 25cm x 25cm, respectively.

C. Analysis

In this paragraph, the measurement value, the proposed index, is actually calculated using the modified box-count method described in the preceding paragraph for measuring the index. Three architectural floor plans shown in Fig. 3 are used as the objects of this analysis.

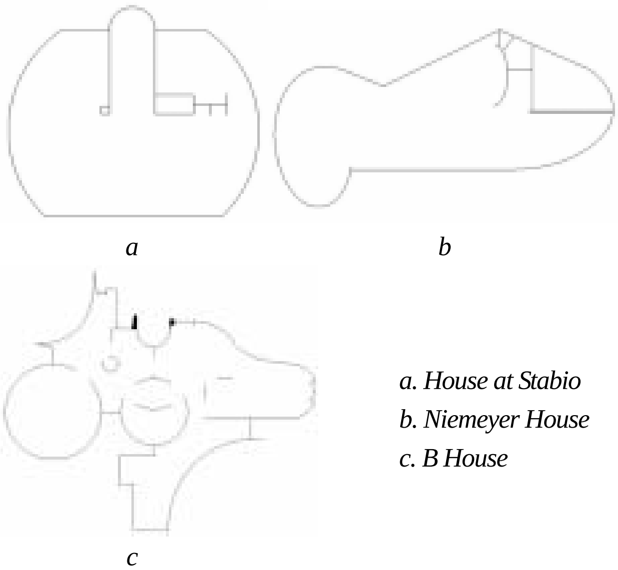
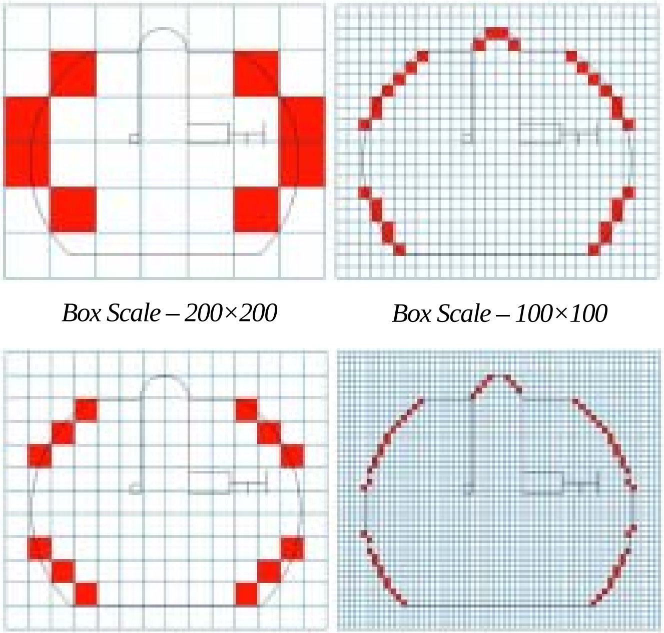


Fig. 3 Objects of the analysis

Fig. 4 shows the boxes extracted on each scale, and the total number of extracted boxes with their logarithmic numbers shown in Table 1. The inclination of the recurrence straight line (Fig. 5) obtained from the full logarithmic table prepared from data in Table 1 is the measured value representing the degree of surprise in this space. The measured value is figured to 1.01.



Box Scale – 200×200 *Box Scale – 100×100*

Box Scale – 50×50 *Box Scale – 25×25*

Fig. 4 Extracted boxes with four different scales

Table 1 The total number of boxes and their logarithmic numbers

Inverse of scale (x_1)	log(x_1)	Box (y_1)	log(y_1)
1/200	-2.301	8	0.903
1/100	-2.000	12	1.079
1/50	-1.699	30	1.477
1/25	-1.398	61	1.785

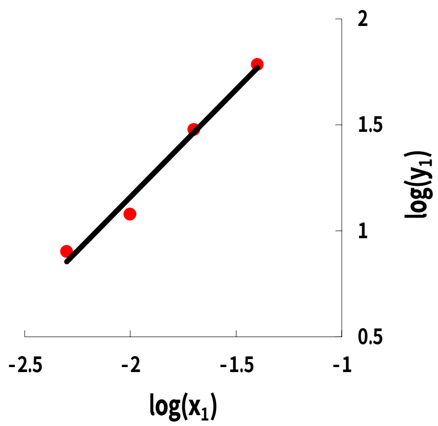


Fig. 5 Full logarithmic table for data listed on Table 1 and the straight recurrence line obtained from the full logarithmic table

Ⅴ. COMPARISON AND FURTHER CONSIDERATION

In the preceding paragraphs, three practical architectural floor plans by world famous architects were chosen to measure the degree of surprise. In this chapter, we compare those measured degrees of surprise. Further, we wish to consider the meaning of those measured numeric values and the relationship between those measured numeric values and the floor plan characteristics of the architectures.

The measured values obtained through this analysis, that is, the degrees of the inclinations of the straight recurrence lines are determined by the ratio that the total number of boxes to be extracted increases for every work step of extracting boxes as the box scale changes during the box extracting process. Namely, the principal factor affecting the rise of measured values can be considered to be the degree of expansion of the range of box extraction that occurs in company with the change (contraction) in box scale.

From here on, we intend to carry this theme forward while collating the measured value of each of three architectural configurations, (the object of the analysis), with the value (Table 2) of the range of extracting boxes on each scale.

Figs. 6 through 8 show rough ranges of extracting boxes (circles in the configurations) in each of three configurations. Comparisons of those configurations would unable the readers to understand the state where the range of extracting boxes in each of those three configurations expands.

As Fig. 6 shows, the range of extracting boxes in the “House at Stabio” changes little on each scale, whereas both the ranges of extracting boxes in the “Niemeyer House”(Fig. 7) and the “B House” increase each time the box scale contracts. Notably, the increasing ratio of the range in the “B House” is at a maximum. Moreover, it is proved that the state of the range of extracting boxes relates to the differences in the measured values (Table 2). That is, the measured value in the “House at Stabio” where the range of extracting boxes expands little falls at a value slightly higher than 1.00, whereas the measured value in the “B House” greatly exceeds 1.00.

Table.2 Comparison of the range of extracting boxes and the measured values of the three houses

Box Scale	House at Stabio	Niemeyer House	B House
200×200	2	4	4
100×100	2	5	8
50×50	3	6	11
25×25	3	7	12
Measured value	1.01	1.14	1.32

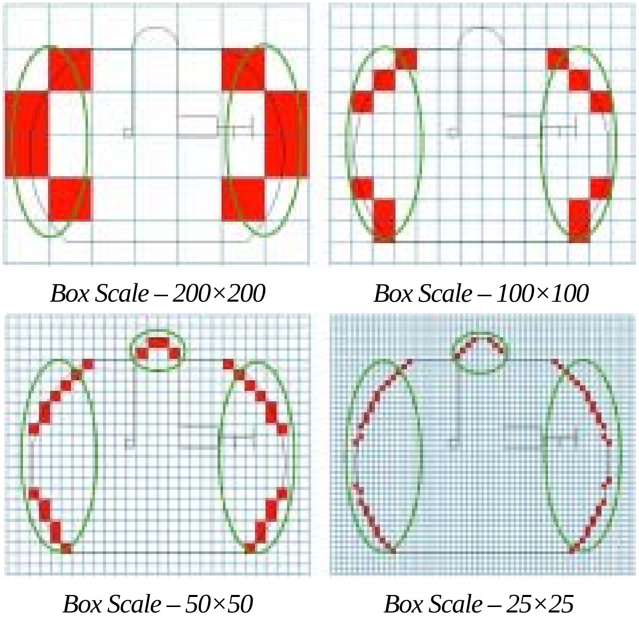


Fig. 6 The ranges of extracting boxes in the “House at Stabio”

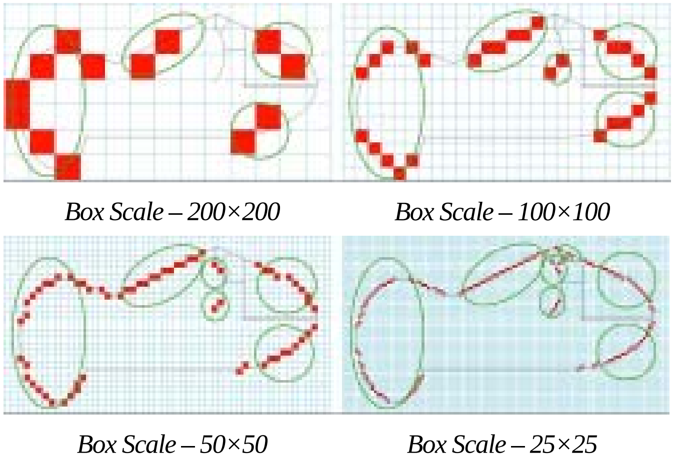


Fig. 7 The ranges of extracting boxes in the “Niemeyer House”

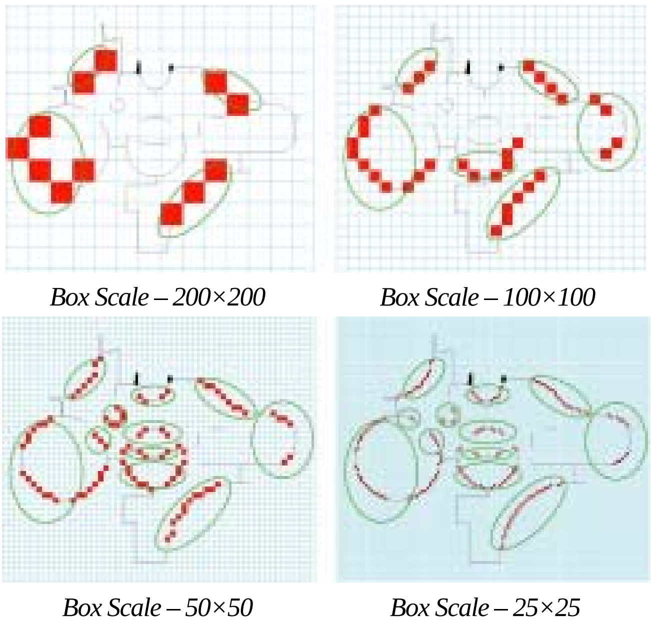


Fig.8 The ranges of extracting boxes in the “B House”

As stated before, the change in box scale means the change in relative distance between the space and a person experiencing the space, assuming that the person experiencing the space is the existence moving around freely inside the space. Namely, the fact that the range of extracting boxes expands with the change in box scale means that various new sights come rushing to the eyes of the person experiencing the space while moving about freely inside the space (all possible positions inside the objective configuration). On the contrary, it can be said that the space within which a change in the range of extracting boxes is little seen shows the person experiencing the space only those sights appearing from a configuration nearly equal to the space regardless of where the person experiencing the space is positioned.

Considering how strongly the modified box-count for non-rectangular configuration can eliminate the tiresome impression in a monotonous space for a person experiencing the space as described in Chapter Ⅱ of this article, the modified box-count method satisfies its existence only after the person experiencing the space eliminates the tiresome impression of the monotonous space configuration by giving the person a great variety of sights, giving the person visual surprises. In other words, it can be said that the higher the measured value of a configuration is (obtained by the modified-count method proposed in this article), the closer is the accomplishment of the aforementioned requirement of the obtained floor plan.

Ⅵ. CONCLUSIONS

The features that the modified box-count method proposed in this article shows when the measured value by that method is applied to architectural floor plans are as follows.

1) As the range of extracting boxes from the objective configuration increases in company with the change in box scale, the measured value of the objective configuration gets higher.

2) Taking an architectural floor plan having a complexity of box scales ranging from large to small as an architectural motif, results in a measured value higher than that obtained by taking an architectural configuration having a simple box scale as a motif.

In other words, it can be considered that this index is a ruler for measuring the complexity of a floor plan, and sufficiently satisfies the purpose of this article for finding an index indicating one aspect of the features of architectural floor plan.

As a future project, we are considering how to enable the modified box-count method proposed in this article for dealing with the three-dimensional analysis of an architectural floor plan. The resultant effects and attempts of all the plastic formations and designs become different dependent on whether those plastic formations and designs are two-dimensionally analyzed as plans or three-dimensionally analyzed as spaces. Only an analytical method adaptable for both plastic formations and designs can probably become a new breakthrough. Further, we are of the opinion that the objective configurations for the modified box-count method can be extended not only to architecture, but also more widely to various plastic formations.

ACKNOWLEDGEMENTS

This study was supported by the Japan Society for the Promotion of Science (2004 Grant-in-Aid for Scientific Research, Scientific Research(A)(1), No.14205087:System Design for Architecture, Urban and Social Systems Adapting to Human and Environment by Complexity Science), and was also supported by Shouei Architects (Representative:Yasunori Nakazawa).

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