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Discontinuous phenomena of holonic design: functional completeness versus solution completeness

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Abstract

Sustainable development should offer a holistic way of resolution of many sharp objective conflicting goals in design. In this context, the question about the stability of models can be raised. The design can be seen as a qualitative discontinuity phenomenon in a continuous background. Understanding and controlling the discontinuity is therefore an important subject of the design research. This paper uses the concepts of the holon and the attractor to analyze the discontinuity. A multi-scale design model is proposed. The proposed multi-scale model is driven by two conflicting drives: (a) completeness of functions and design parameters and (b) discrimination of functions and design parameters. Completeness has been seen as the degree to which a function or a design parameter is recognized to be fully satisfied in a holon. Discrimination can be seen as the degree to which a function (respectively design parameter) refuses to recognize design parameters of other holons. By employing creation of holons as an indicator of the holon's state, we attempt to learn how the holon's behaviour varies as function of completeness and discrimination. Thus two control parameters: (a) completeness of design parameters and (b) completeness of functions, have been defined. The behavior of the holon design defines the output. Then, the discovered possible states of behavior of holon design are: a) impossibility state characterized by the impossibility of holon creation; b) creation-destruction state characterized sometimes by the creation of holons and sometimes the destruction of holons; c) creation-development state characterized by natural creation and development of the holon. The model shows that design is not an orderly and well behaved phenomenon. Design is full of sudden transformations and unpredictable divergences. The task of modeling these problems and relating them to each other would be a challenging endeavor which requires more powerful theory.

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Keywords: Sustainable design; multi-scale design; holon design; cellular design.

1. Introduction

Sustainable development should offer a holistic way of resolution of many sharp objective conflicting goals in design. Designers can engage the current challenge of sustainable development applying also the "the long term ability of a system to reproduce [1]" criterion. Design and design components should be self-sustains objects. Therefore, the modeling of components needs to be self-sustaining. How these system components need to be designed such that they are self-sustain, self-stand and suited for integration is an important subject of research on emergent behavior [2]. Building self-sustain models is not a simple problem for engineers. If the models are self-sustain then they should be capable of adapting themselves to the new situations.

In this context, the question about the stability of models can be raised. The stability of model depends on the interactions between elementary models which constitute it and their respective forms. The design in the last analysis can be seen as a qualitative discontinuity phenomenon in a continuous background. Understanding and controlling the discontinuity is therefore an important subject of the design research.

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Holons is a very interesting concept to represent the distinction continu-discontinu. The idea of the “holon” was introduced by Arthur Koestler [3]. The holon is a whole that is part of a vaster whole, and which at the same time contains elements, or sub-parts, of which it is composed and which provide its structural and functional meaning. The holon represents a very interesting way to overcome the dichotomy between parts and wholes and to account for both the self-assertive and the integrative tendencies of an organism.

The other important concept to analyze the continu-discontinu design phenomenon is the attractor. By employing the attractors and the creation of holons as an indicator of the holon’s state, we attempt to learn how the holon’s behaviour varies as function of two drives: completeness and discrimination. Completeness has been seen as the degree to which a function or a design parameter is recognized to be fully satisfied in a holon. Discrimination can be seen as the degree to which a function (respectively design parameter) refuses to recognize design parameters of other holons.

The paper is organized as following: In the second section, the definition of holons and their characteristics is proposed. In the third section, we specify our working hypotheses. We also present the heuristic for the constitution of the cellular cells, which is inspired by the generation of the holonic structures. In the forth section, the three found models are presented. The conclusions and the perspectives of this research study are finally presented.

2. State of art

Many applications have been executed using the notion of holon. However, the contribution of the holon paradigm in the scientific literature goes further beyond applications [4]. Fundamental insights into Holonic Systems Design, augmented with more recent research results on complex adaptive systems and discusses implications for the design of Holonic Multi-Agent Systems are presented in [2]. For every holonic manufacturing system, there are three types of basic holons, namely resource holons, product holons, and order holons [5-6-7]. The application of holonic concepts to manufacturing was initially motivated by the inadequacy of existing manufacturing systems in the following two aspects: (a) dealing with the evolution of products within an existing production facility, and (b) maintaining a satisfactory performance outside of normal operating conditions [8]. Holonic control has been studied as well as holonic manufacturing. Holonic control combines the advantages of traditional control systems, for instance hierarchical control, and avoids their drawbacks [6-9-10]. Control approaches for holonic manufacturing systems were proposed by [11], [12] and [13].

Structural holarchies of the fractal type are used in concurrent engineering [14]. Self-similarity of engineering design process is used to structure the engineering design process into fractal based concurrent engineering. Holons have been also used in product and system design. The design holon, according to [15], consists of three elements: (a) a problem, (b) a solution which is synthesized for this problem, and (c) the decomposition of the problem into sub-problems based on the chosen solution. Holon networks has been used effectively for the identification of large-scale nonlinear dynamical systems. A holonic modeling of complicated systems, such as complex adaptive systems which bring a new paradigm of science is presented in [16]. Another application of holonic concept is Holonic assembly [17]. The fault tolerant properties of holonic assembly/disassembly processes in holonic manufacturing systems have been studied in [18].

One of the most important properties of holon is that it exchanges information, material, or resources with other holons via its interfaces through negotiation and cooperation. It can also form a part of another holon. A set of constraints on the actions of holon indicates its tendency to be whole and part. The holon is defined by the position it occupies and by the direction of observation [19]. Warnecke defines the holons as an independently acting corporate entity whose goals and performance can be precisely described [20].

The architecture of holons shows ‘horizontal’ and ‘vertical’ self-similarity. Horizontal self-similarity relates to self-similarity across different specializations on one level of aggregation. Vertical self-similarity refers to self-similarity across different levels of aggregation: higher-level resource holons work similar to lower-level resource holons. The ‘horizontal’ and ‘vertical’ self-similarity are presented by [21] The complex systems involve not only natural systems such as environmental phenomena and ecological systems but also artificial systems such as designs. It is therefore important to study what model is effectual for the grasping the behavior of the complex design systems.

3. Holon Design Model

We define a design cell as a holon entity. A design is to be regarded as a multi-leveled hierarchy of semi-autonomous sub-wholes, branching into sub-wholes of a lower order, and so on to form a holon. Each sub-whole within the hierarchic tree has two properties: it is a whole relative to its own constituent parts, and at the same time a part of the larger whole above it in the hierarchy.

One of the essential requirements of the design cell is the capacity for independent actions. Thus, when several elements of the holon are defined on the same substrate, through their interaction between them, often they can end up in conflicts. The conflict between these different elements can be spatially organized in a structurally stable configuration, itself governed by a higher-level substrate.

Thus the first hypothesis of the proposed approach is that a mulit-scale design can be represented by a holon structure defined by: (a) *Functions holons represented by a holonic network of functions;(b) Solutions holons represented by a holonic network of solutions, and (c) Design holons, representing the relationship between function holons and solution holons*

The first hypothesis means creating "design cells within a design cell". Thus, the first hypothesis allows structuring the design into different levels of "design cells within a design cell". The internal relationships within a design are closer and more intensive than the relations with the outside. The second hypothesis of our work postulates that functions holons, solutions holons and design holons have some elementary elements called primitive elements of the corresponding holon structure. The second hypothesis, by defining the primitive elements, allows seeking the different levels of "design cells within a design cell".

The objective of multi-scale design is then the creation of the design cells so that interactions between elements inside the design cells are maximized. For the design cells, first, we propose some properties relating to their formation. Second, we propose an algorithm which draws its inspiration from the holon structure generation [14] and which satisfies these properties. Properties relating to design cell formation are the following:

• *Property 1: Design cell is a Holon.*

This property stipulates that a design cell is a holon. This property is used for seeking "design cells within a design cell". Each holon corresponds to a substrate or level of "design cells within a design cell".

• *Property 2: Fusion.*

This property implies the fusion of a design function (singleton or macro-design function) of the set of design functions with a design parameter (singleton or macro-design parameter) of the set of design parameters, if they are related.

• *Property 3: Condition of transfer.*

This property stipulates that the contribution of a design function *i* (respectively design parameter *j*) to its own design cell must be greater than its contribution to all the other design cells.

• *Property 4: Condition of admission.*

This property stipulates that the contribution of function or a parameter to a cell must be greater than or equal to an admission value. If the value of the admissible coefficient of attraction, noted ACA, is significant, for example equal to 1, then attraction between the design parameters (respectively design functions) is also significant.

• *Property 5: Conditions for attractor selection.*

This property stipulates that one initial design parameter (respectively design function) must be initially assigned to a unique cell. These initial design parameters (respectively design functions) are called attractor design parameters (respectively design functions). An unassigned design parameter (respectively design function) is chosen as attractor so that it has one of the following properties:

• *Property 6: Equivalent solutions.*

This property stipulates that the construction of equivalent solutions rest on the possibility that design function *i* (respectively design parameter *j*) has to be able to contribute in an equal way to several cells.

• *Property 7: Relationship of preference.*

This property stipulates that one can build a preference relationship in the set of the design functions (respectively design parameters). In this case design function *i* (respectively design parameter *j*) can be weighted by weight w_i (respectively w_j).

The uncertainty is an integral part of the design process. It is not imprecision in logic, but rather the intrinsic vagueness of a preliminary, incomplete or fuzzy design description [22]. In order to capture the uncertainty aspects that characterize this process, we propose the use of the fuzzy sets approach [23]. Thus, a fuzzy relationship can be defined between the set of functions and set of design parameters. In this interpretation the values show the degree of interaction between a function and a design parameter. Hence, the designer could use an intermediate degree between 1 and 0.

4. Application

By employing creation of holons as an indicator of the holon's state, we attempt to learn how the holon's behavior varies as function of completeness and discrimination. If only one of the conflicting factors is present the response of the holon is relatively easy to predict. Completeness can be seen as the degree to which a function (respectively design parameters) is recognized to be fully satisfied in a cell holon by all design parameters (respectively functions) affected in this cell holon. Discrimination can be seen as the degree to which a function (respectively design parameters) refuses to recognize all design parameters (respectively functions) of other holons.

If the holon should be complete in the regard of design parameters, but the discrimination in term of functions is not required, then holon creation around the attraction potential of design parameters can be expected. If the holon should be complete in the regard of functions but not discriminate in term of design parameters then holon creation around the attraction potential of function can be expected.

If the holon should be (a) complete both in respect of design parameters and functions or (b) complete in respect of design parameters and discriminate in terms of functions then two controlling factors seems to be in direct conflict.

Thus, two control parameters: completeness of design parameters and completeness of functions can be defined. The behavior of the holon design defines the output. The possible states of behavior of holon design are:

a) *Impossibility state* characterized by the impossibility of cell creation;

b) *Creation-development state* characterized by natural creation and development of the holon.

c) *Creation-destruction state* characterized sometimes by the creation of cells and sometimes the destruction of cells;

For the same design function-design parameter network, the quality of the design holons depends on the value of the acceptable coefficient of attraction. The lower the acceptable coefficient of attraction value is, the less variation of possible states is (Table 1).

Table 1. Behavior of holon design

State	Non destroyed attractors Values of ACA	Destroyed attractors Values of ACA	Destroyed and returned attractors Values of ACA
One State	0.1; 0.2; 0.3; 0.4		
Two states		0.5; 0.8; 0.9	
Three states		0.7 0.9->0.7->0.5->0.1 0.9->0.6->0.1	0.6

Figure 1 shows the variation of potential attractors with the acceptable coefficient of attraction value equal to 0.1. There is only one state *Creation-development*. The holon is created and developed around the potential design parameters attractors. Therefore, these attractors are strong.

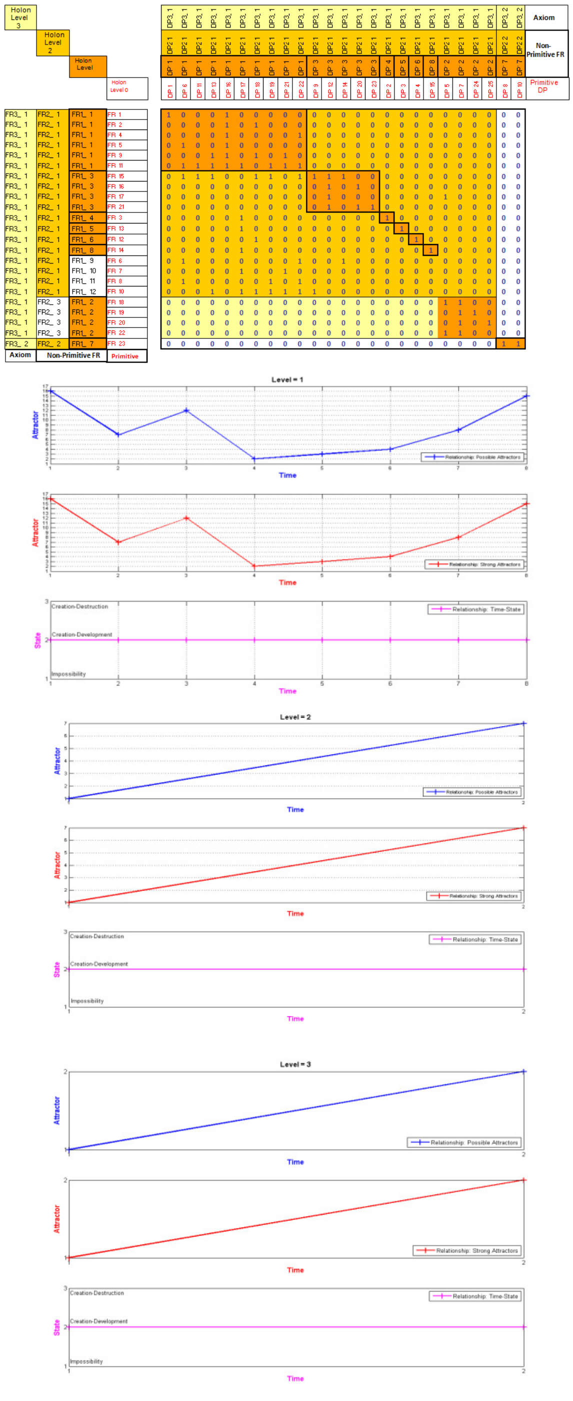
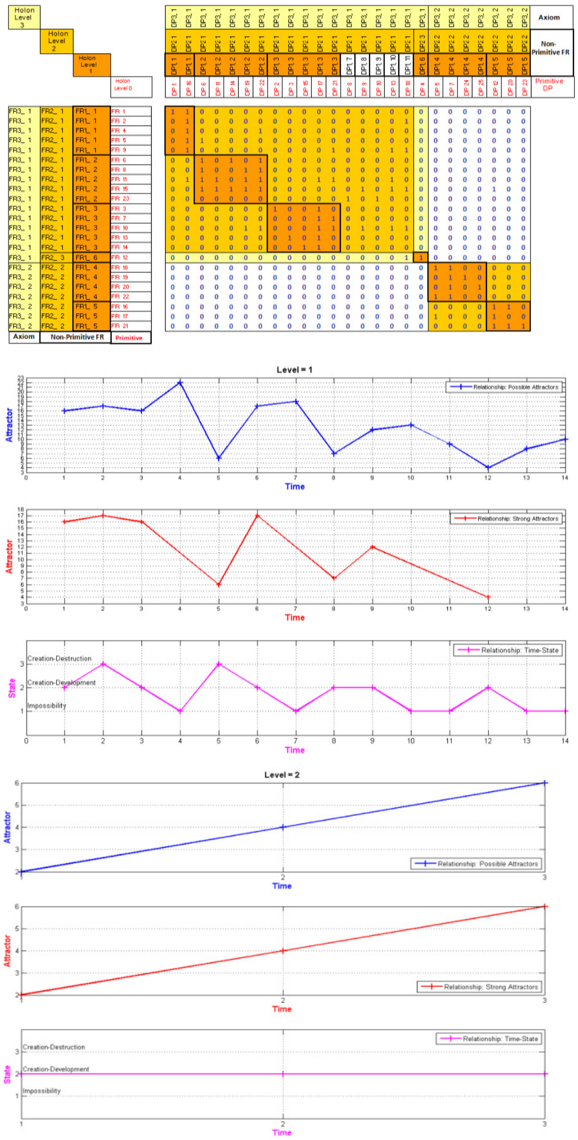


Fig. 1. Three levels of holons with ACA=0.1 and for each level (a) Possible attractors; (b) Strong attractors; (c) States.

For some values of the control variables, where either completeness of design parameters or completeness of functions is predominant, there will be holon creation-development behavior. For the central values of the control variables, where completeness of design parameters or completeness of functions are roughly equal, two or three behaviors of holon design has been distinguished. By increasing the value of the acceptable coefficient of attraction, the relations between the design parameters inside the design cells will become stronger. Consequently, some potential attractors are not capable to create the cells. The holon reach the impossibility state.

Figure 2 shows the variation of potential attractors with the acceptable coefficient of attraction value equal to 0.6 for the three levels of holon design. The holon design comes along three states during the first level. In this level, some possible attractors are not capable to create cells.



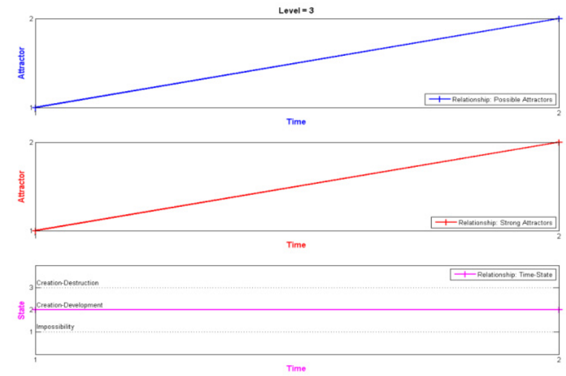


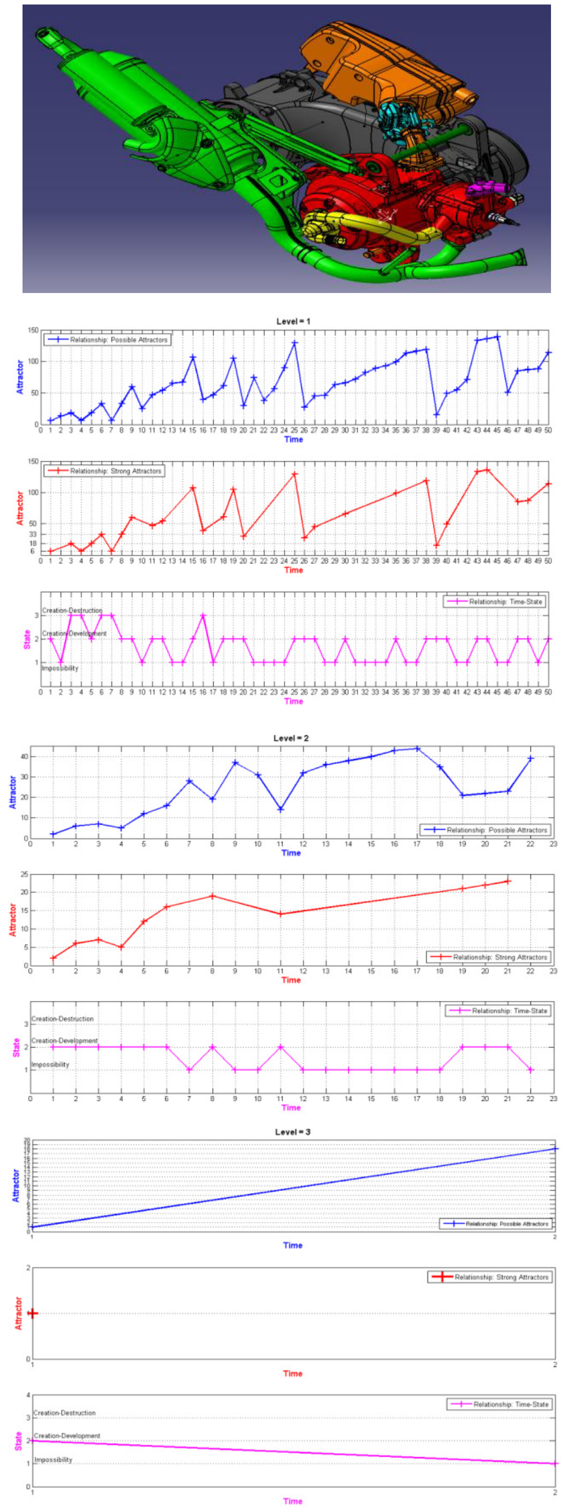
Fig. 2. Three levels of holons with ACA=0.6 and for each level (a) Possible attractors; (b) Strong attractors; (c) States.

If increases the degree of completeness is increased (through the coefficient of admission) without affecting the degree of completeness of functions (through the propriety of transfer), the behavior of the holon changes to more strong attitudes in the relationship between design parameters and function. This is the state of the development. If the value of the degree of completeness is increased as much as necessary, the holon falls from the state development, to the state of the impossibility. In this case, some possible attractors are not capable to create cells.

If the completeness of functions begins to increase while the completeness of design parameters remains at an elevated level, the holon remains in the state of development. As the completeness of function continues to increase, the behavior state falls to the state of the creation-destruction. The development state is not longer possible; there is no alternative but a sudden change. This change represents a catastrophe according to the theory of catastrophes [24]. This sudden change in behavior of the holon might be called resistance catastrophe. Thus, the model shows that if a completed holon in terms of design parameters is made progressively completed in term of functions, it will eventually break off its natural development and resist to fall to the impossibility behavior (Table 1).

A similar pattern of behavior exists when the attractors are functions. In an initial state dominated by the completeness of function, but with a sufficient increase in completeness of design parameters, the design holon passes from the state of the development to the state of creation and destruction. Finally, a sufficient increase in completeness of function falls the design holon in the impossibility state as shown in figure 2 Level 1, at Time=4; 7; 10; 11; 13; 14.

The network design parameter–design parameter of the design of a block-engine of a Scoter is considered as entry for a second application. Two control parameters: completeness of design parameters and completeness of functions has been used. The behaviour of the holon design of a block-engine defines the output. In the first level, the possible states of behaviour of holon design block-engine are: a) *Impossibility state*; b) *Creation-development* state and c) *Creation-destruction state*. In the other levels, the behaviour of the holon design is characterised by Creation-development state. Block-engine of a Scoter example shows that our proposed approach is applicable on complex systems (Fig. 3). Table 2 shows the relationship between states of behaviour and the attractors.



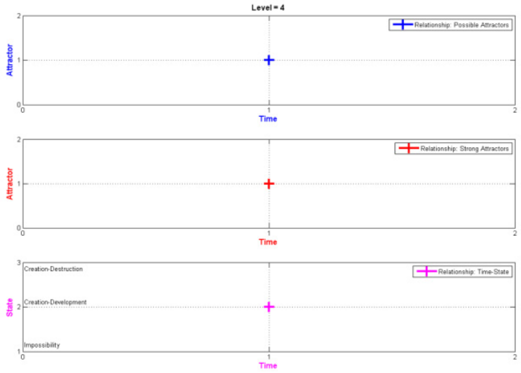


Fig. 3. CAD model of block-engine of a Scoter: Four levels of holon with ACA=0.6 and for each level (a) Possible attractors; (b) Strong attractors; (c) States.

Table 2. Behavior of holon design of a block-engine of a Scoter

State	Non destroyed attractors Values of ACA	Destroyed attractors Values of ACA	Destroyed and returned attractors Values of ACA
One State	0.1; 0.2; 0.3		
Two states		0.8; 0.9	
Three states			0.4; 0.5; 0.6; 0.7 0.9->0.8->0.7

5. Conclusion

Understanding and controlling the discontinuity is therefore an important subject of the design research. Holons is a very interesting concept to represent the distinction continu-discontinu phenomena in design. The other important concept to analyse the continu-discontinu design phenomenon is the attractor. Concepts of the holon and the attractor allow multi-scale design. It means designing "design cells within a design cell". The proposed holon model is implicitly driven by two conflicting drives: (a) completeness of functions and design parameters and (b) discrimination of functions and design parameters. Three possible states of behavior of holon design are found: a) impossibility state characterized by the impossibility of holon creation; b) creation and destruction state characterized sometimes by the creation of holons and sometimes the destruction of holons; c) development state characterized by natural creation and development of the holon.

The model has shown that if a completed holon in terms of design parameters is made progressively completed in term of functions, it will eventually break off its natural development and resist to fall to the impossibility behavior. The model shows that design is not an orderly and well behaved phenomenon. Design is full of sudden transformations and unpredictable divergences. The task of modeling these problems and relating them to each other would be a challenging endeavor which requires more powerful theory.

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