Implementation of Complexity Analyzing based on Additional Effect

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Abstract. According to the Complexity Theory, there is complexity in the system when the functional requirement is not be satisfied. There are several study performances for Complexity Theory based on Axiomatic Design. However, they focus on reducing the complexity in their study and no one focus on method of analyzing the complexity in the system. Therefore, this paper put forth a method of analyzing the complexity which is sought to make up the deficiency of the researches. In order to discussing the method of analyzing the complexity based on additional effect, this paper put forth two concepts which are ideal effect and additional effect. The method of analyzing complexity based on additional effect combines Complexity Theory with Theory of Inventive Problem Solving (TRIZ). It is helpful for designers to analyze the complexity by using additional effect. A case study shows the application of the process.

Keywords: Complexity theory，TRIZ，Additional Effect

1. Introduction

The Complexity Theory [1] based on the Axiomatic Design method is an important means of complexity elimination which Suh put forth. Suh identifies the concept of the complexity. According to the Complexity Theory based on the Axiomatic Design, the system is complex when the functional requirement is not satisfied. Suh was studied on the complexity elimination in the Complexity Theory based on the Axiomatic Design. Suh puts forth the c/p transformation to reduce time dependent complexity. There are several study performances for Complexity Theory based on Axiomatic Design. Liu [2] has investigated how to use TRIZ tools to reduce system's complexity. Zhang [3] proposes that designers can reduce the complexity by a design model which combines Complexity Theory based on Axiomatic Design with evolution path in TRIZ. They focus on reducing the complexity in their study and no one focus on the method of analyzing the complexity in the system. Therefore, this paper put forth a method to analyze the complexity.

In order to establish method of analyzing the complexity based on additional effect, this paper put forth two concepts which are ideal effect and additional effect. The ideal effect is the effect that can realize the functional requirement in the system and the additional effect is the effect which is an obstacle of realizing the functional requirement. The method combines Complexity Theory based on Axiomatic Design with Theory of Inventive Problem Solving (TRIZ) [4]. The process is helpful for designers to analyze the complexity. A case study shows the application of the process.

2 Methodology

2.1 Complexity Theory based on Axiomatic Design

N.P. Suh put forth the Complexity Theory based on the Axiomatic Design method. Complexity is defined as a measure of uncertainty in achieving the functional requirements (FRs) of a system [1]. The overlap between design range and system range is called common range, which is shown in Fig.1 [1].

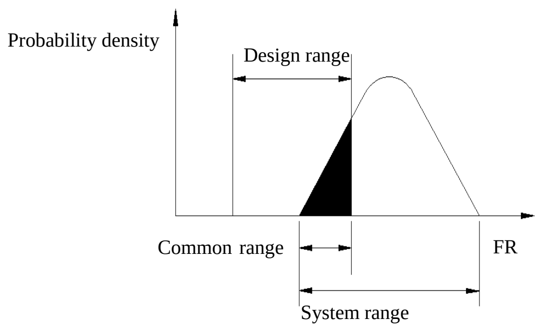

Fig. 1. Relation among design range, system range and common range

Complexity is a function of the relationship between the design range and the system range [5]. The FR is satisfied only when the system range overlaps the design range indicated by the common range. When the system range is not completely in the design range, there is a finite uncertainty that the FR may not be satisfied. A design is called complex when its probability of success is low, that is, when the information content required to satisfy the FRs is high [5].

2.2 Ideal Effect and Additional Effect

Effect is one of the knowledge base tools in TRIZ. Emerged from the analysis of hundreds of thousands patents by finding relevance between a technical function delivered by a design product described in a patent and an effect used as a principle for the product [4]. Under "effect" we will understand the related laws, theorems, phenomenon, and alternative methods in the same or other domains by which the problems in design are solved, and the effect can be characterized by its input, output relations [6].

The additional effect is put forward on the basis of effect concept in TRIZ. The effect that can meet the functional requirements is the ideal effect [7]; effect that causes complex problems of system is the additional one. The ideal effect, as shown in Fig.2, is the effect that can realize the functional requirement in the system and the additional effect is the effect which is an obstacle of realizing the functional requirement. Usually, additional effect is caused by the following factors: noise, coupling, environment and random variables in the design parameters.

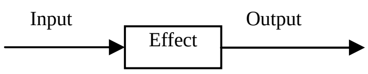

Fig.2. Ideal effect

If there is only one Input that is related to its Output as:

$$OUT = f_E(IN) \quad (1)$$

3 Complexity Analyzing based on Additional Effect

Complexity is the function of design range and system range. According to the complexity theory, designers should determine in the functional domain whether there are complex problems exist in the system, which actually is a comparatively difficult process. We analyze the system's complexity according to nothing more than the concept of the complexity presently, which brings much inconvenience to the designers who analyze the system's complexity using Complexity Theory. The purpose of design is to meet functional requirements while function could be expressed by its corresponding effect. Therefore, we can analyze the complexity by using the effect module. How do we transform the complexity into effect?

3.1 b The mapping of the complexity

Designers could determine the complex problems in the system through its performance in the physical domain. Here, we define the complex problems in the physical domain as event of complex problems. It is comparatively simple to obtain events of complex problems. To describe the complex problems of a system, designers should map the events of complex problem in physical domain into the ones in functional domain, the process of which is defined as the first mapping. To explicitly describe the complex problems of a system, complex problems in the functional domain should be mapped as additional effects, the process of which is called the second mapping of complex problems. Events of complex problems in physical domain are caused by problem functions in functional domain, while the ones in system are caused by additional effects. Complex problems in functional domain will be transformed into additional effect through the second mapping of complex problems. A new analyzing model of complex problem on the basis on effect will be established through the first and the second mapping of complex problems. The process of twice mapping of complex problems is shown as the Fig. 3.

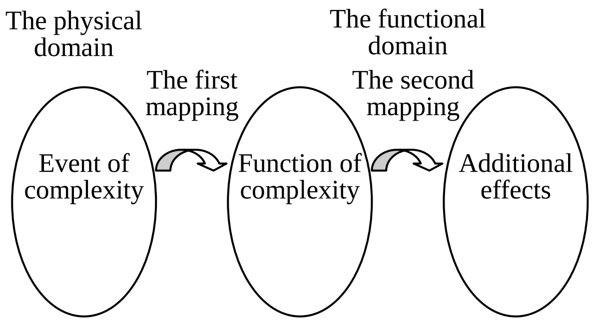

Fig. 3. The twice mapping of complexity

When complex problems in the functional domain are mapped as additional effects, we will reduce the influence of the additional effects. How do we reduce the additional effects if there are several additional effects? We must classify the additional effects.

3.2 The Classification of additional effects

Due to the fact that many factors may cause additional effects, there are several methods to classify them. Additional effects may be caused by inside and outside factors of a system in terms of their origin. While, they can be divided into ones that could affect input or output of ideal effects according to their ways of affecting the system. Therefore, we put forward 5 models that their systems may show complexities due to additional effects according to the above mentioned two classifications.

1. Affecting ideal effects' input by additional effects inside the system which is shown as Fig.4a.
2. Affecting ideal effects' output by additional effects inside the system which is shown as Fig.4b.
3. Affecting ideal effects' input by additional effects outside the system which is

shown as Fig.4c.

4. Affecting ideal effects' output by additional effects outside the system which is shown as Fig.4d.
5. Additional effects that fail the ideal effects which is shown as Fig.4e.

In figure 4a, the function output OUT is given by

$$OUT = f_E(IN + f_{Ea}(IN_a)) \qquad \textbf{(2)}$$

In figure 4b, the function output OUT is given by

$$OUT = f_E(IN) + f_{Ea}(IN_a) \qquad \textbf{(3)}$$

In figure 4c, the function output OUT is given by

$$OUT = f_E(IN + f_{Ea}^{'}(IN_a^{'})) \qquad \textbf{(4)}$$

In figure 4d, the function output OUT is given by

$$OUT = f_E(IN\ ) + f_{Ea}^{'}(IN_a^{'}) \qquad \textbf{(5)}$$

In figure 4e, the function output OUT is given by

$$OUT = E_a^{'} \times f_E(IN) \qquad \textbf{(6)}$$

Where f_E is the ideal effect;

– f_{Ea} is the additional effect;
– IN is the ideal effect's input ;
– IN_a is the additional effect's input in the system ;
– $IN_a^{'}$ is the additional effect's input in the super system;
– $E_a^{'}$ is additional effect's input that fail the ideal effects.

According to 5 models, OUT may be expressed as

$$OUT = E_a^{'} \times f_E(IN + f_{Ea1}(IN_{a1}) + f_{Ea4}^{'}(IN_{a4}^{'})) + f_{Ea2}(IN_{a2}) + f_{Ea3}^{'}(IN_{a3}^{'}) \qquad \textbf{(7)}$$

Where f_{Ea1}, f_{Ea2} are the additional effects;

– IN_{a1}, IN_{a2} are the additional effects' input in the system;
– $IN_{a1}^{'}$, $IN_{a2}^{'}$ are the additional effect s' input in the super system.

To sum up, several factors could affect ideal effects which are $E_a^{'}$, $f_{Ea1}(IN_{a1})$, $f_{Ea2}(IN_{a2})$, $f_{Ea3}^{'}(IN_{a3}^{'})$ and $f_{Ea4}^{'}(IN_{a4}^{'})$.The 5 models could be classified into three categories on the basis of the degree of difficulty to find the solution for the system with additional effects which is shown as Fig.5.

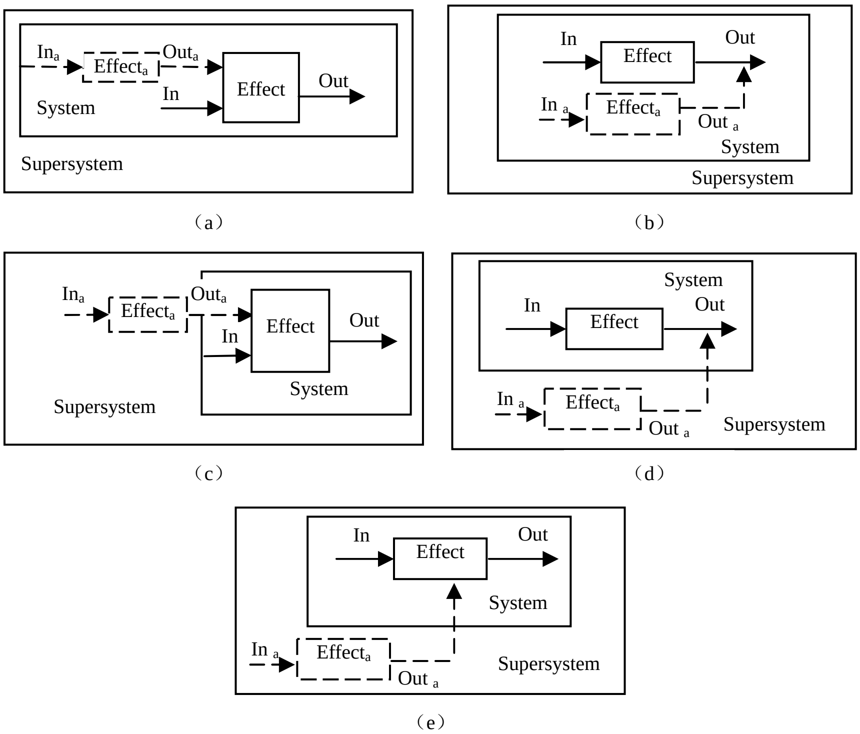

Fig.4. Additional effect

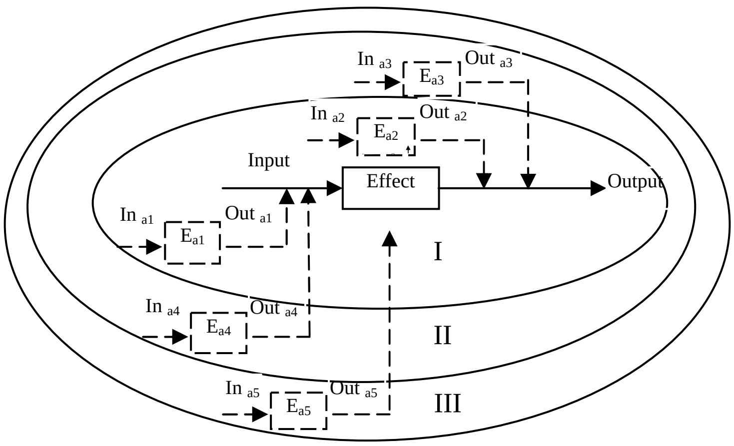

Fig.5. The 5 models of additional effect

I. Additional effects inside the system are the first kind of additional effects. It refers to the condition that additional effects internally affect the input and output of ideal effects. Several ways may solve this problem. For instance, firstly, to analyze the additional effects of the system by addition effect analyzing method, and then, find the solution by TRIZ theory; or, to find the solution for complexities of the system by complexity theory; also, TRIZ tools could be used directly for it, such as 40 inventive principles.

II. Additional effects outside the system are the second kind of additional effects. This refers to the condition that effects externally affect the input and output of ideal effects of the system. Also, several ways may solve this problem, for example, analyzing the additional effects of the system first by additional effect analyzing method, and then to find the solution by TRIZ theory; c/p process in complexity theory could also be used to solve this problem (c/p process could only solve part of the problem due to the fact that it can only be applied in the systems that exist repeat functional sets); substance-field analyzing may also be used to reach the purpose.

III. Additional effects that fail the ideal effects are the third kind of additional effects. Ideal effects could be failed when this category existing in the system. It’s comparatively difficult to deal with the problem. Both complexity theory and TRIZ theory may confront obstacles when directly being used for analyzing such problems. Therefore, it would be appropriate to analyze additional effects by additional effect analyzing method first, and then to find the solution by TRIZ theory.

First of all, we must eliminate the third kinds of additional effects which can fail the ideal effects because they are the most harmful in all of the additional effects. Secondly, when there are not the third kinds of additional effects in the system, we may reduce the influence of the second kinds of additional effects which is in the super system. At last, we obtain the solutions of the first kinds of additional effects.

The process of obtaining the solution of additional effects is shown as Fig.6. complexity in the functional domain are mapped as additional effects first, then the third kind of additional effects, the second kind of additional effects and the first kind of additional effects would be reduced one by one. If we can not obtain some solutions of additional effect, we can obtain some new effects by using CAIs. At last, we identify whether the system’s additional effects are reduced or not and whether the functional requirement has been satisfied.

4 A Case Study

We design a system which could receive echo of ultrasonic wave in water which is shown as Fig.7. The system measures the time of ultrasonic wave returning to the sensor and calculates its transmitting distance in the medium by sound speed [8].

We can express the magnitude of the echo of ultrasonic sound as the electrical signal. Comparing the electrical signal with a fixed reference voltage, the receiving signal of ultrasonic wave is obtained. If the electrical signal is higher than the reference voltage, the receiving time will be recorded. If the electrical signal is lower, it is considered that there is no receiving signal of ultrasonic. In general, the measuring values should be constant in the same condition. However, there are still differences among measuring values. Since the system couldn’t be measured precisely, there exist complexities in the system. There are three complex problems in the system.

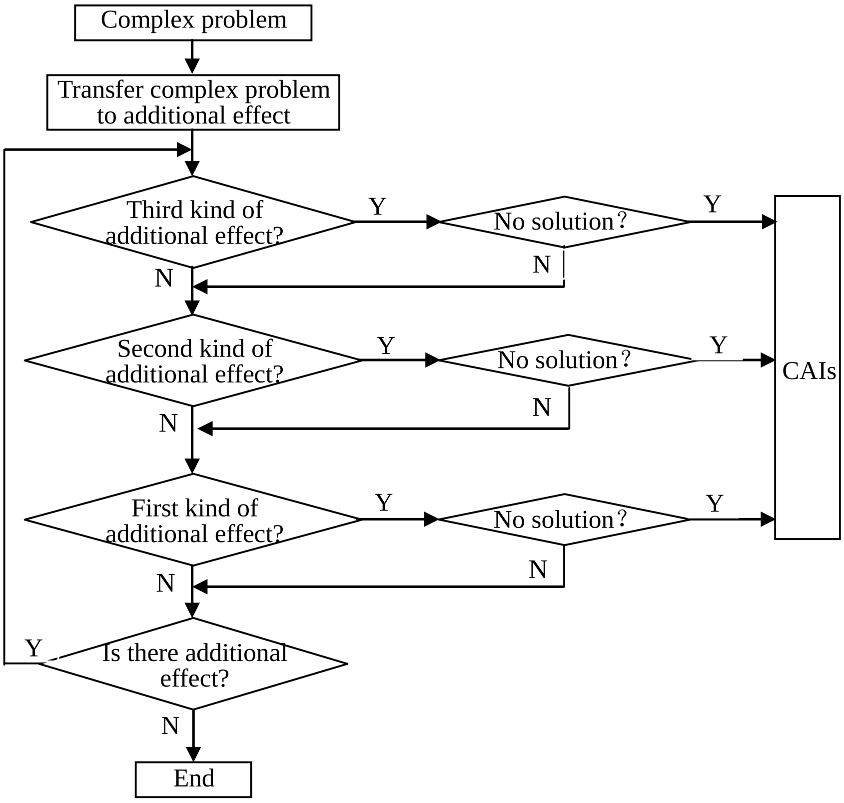

Fig. 6. The process of obtaining the solution of additional effects

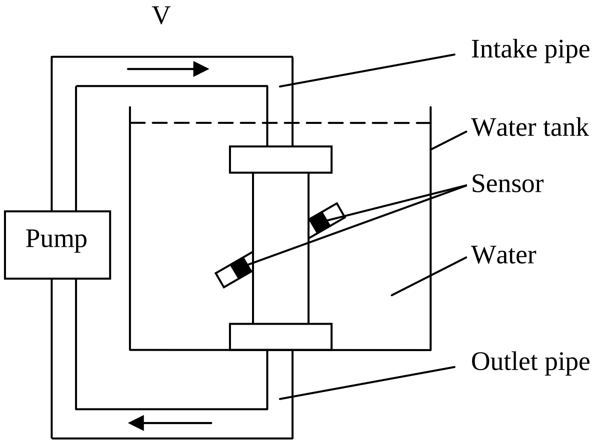

Fig. 1. The ultrasonic system

1. When water is flowing in the pipe, the ultrasonic signal becomes smaller and

smaller. At last, the ultrasonic signal disappeared. The measure is complete failure.

2. In general, the measuring values should be constant in the same condition. At a certain time, the measuring value is larger than normal one while the electrical signal is lower than normal one. However, the electrical signal can return to normal.
3. Similarly, we obtain the measuring values in the same condition. At a certain time, the measuring value is smaller than normal one but the electrical signal do not change obviously. The measuring values are almost identical which are smaller than normal one.

In view of the above problems， the method of analyzing the complexity by additional effects can be used to analyze this system.

1. The ultrasonic signal diminishes if the ultrasonic sensors in liquid are propagated in air. There are little gas bubbles on the ultrasonic sensors when water is not flowing in the water tank. When water is flowing, the gas bubbles become more and more on the ultrasonic sensors while the receiving signal of ultrasonic becomes smaller and smaller. At last, the ultrasonic sensors can not work. According to the problem one, there exists the fully attenuation effect in the super system, and the ideal effect is complete failure. The fully attenuation effect belongs to the third kind of additional effects.
2. When water flows, there are the gas bubbles in water. The ultrasonic signal will diminish if the ultrasonic signal crosses the gas bubbles. Therefore the electrical signal is lower than normal one. According to the problem two, there exists partial attenuation effect in the super system. The partial attenuation effect belongs to the second kind of additional effects.
3. There is a function of dynamic channel switching at a fixed time and this function will produce a switch signal. The coupling disturbance for the switch signal is coupled with the receiving electrical signal of ultrasonic. In fact, the measuring values, which are smaller than normal one, are the time of the switch signal. Therefore, there is an additional effect which is electromagnetic interference effect in the system. So it belongs to the first kind of additional effects.

To sum up, there are fully attenuation effect, partial attenuation effect and electromagnetic interference effect respectively. According to the classifications of additional effects, we obtain the solutions of fully attenuation effect, partial attenuation effect and electromagnetic interference effect by using CAIs. We never amplify the concrete scheme which is restricted by paper length

5 Conclusions

The case study results show that the method can help designers to solve the complex problem of the ultrasonic system. Moreover analyzing complexity is one of important research in complexity theory. This paper makes a conscientious study of analyzing complexity by using additional effects. At last, a design example of ultrasonic system is presented to demonstrate the method of analyzing the complexity by using additional effects.

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