Time-space-direction extension TRIZ innovation model for product innovation

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Abstract—In order to solve the problem that college students are prone to thinking set and direction deviation in the process of innovation practice. TRIZ (Latin abbreviation of "Teoriya Resheniya Izoblatelskikh Zadatch", which means theory of the solution of innovative problems) is extended and matched with the meta conditional features or quantities of the three dimensions of TSD (time, space and direction) of the problem. In this paper, TRIZ-TSD extension problem solving model is proposed to find compatible solutions. TRIZ-TSD extension problem solving model expands the available resources of the original TRIZ analysis tools, strengthens the interaction between the analysis tools, and makes it more suitable for beginners to use in practical innovation. Taking the university student innovation award-winning project "the intelligent wall planting system" as an example, the basic process and practical effect of TRIZ-TSD fusion innovation model in solving specific problems are verified. The basic principle and thinking mode of this method is not only limited to the practice of College Students' innovation projects, but also has certain reference value for solving problems in other fields.

Keywords—Problem Solving, Innovation Model, TRIZ, Time-Space-Direction Extension.

I. Introduction

Based on the analysis of nearly 2.5 million high-level invention patents, Genrikh Altshuller, a scientist of the former Soviet Union, put forward TRIZ theory to solve the problem of invention. Among them, 40 innovative principles to solve the technical contradiction of invention (also known as technical conflict) are an important part of TRIZ theory, so as to better guide the activities of invention and creation [1].

Compared with other innovative methods, such as Trial-and-Error testing method, brain storming method, TRIZ theory has distinct characteristics and advantages. It successfully reveals the inherent laws and principles of invention creation, and focuses on clarifying and emphasizing

The contradictions in the system, rather than avoiding the contradiction. The goal is to completely solve the contradiction and obtain the ultimate ideal solution, rather than compromise or compromise, and it is based on the development and evolution law of technology to study the whole design and development process, rather than random behavior [2].

Some scholars think that in practical application, the classical TRIZ theory tools are too large, and its application process needs "rigorous analogical thinking". In most cases, the main role is not the TRIZ theory tools themselves, but the intuition and insight of the parties [3]. Altshuller himself proposed in his classic works that TRIZ is mainly suitable for those highly intelligent and experienced inventors [4].

Other scholars think that TRIZ theory's solution procedure for invention problems is too abstract, and it is a big jump from specific invention problems to standard invention problems and from corresponding principle solutions to practical solutions [5], [6]. Moreover, TRIZ theory's related methods lack clear operation objects, which is not in line with people's practical thinking habits when dealing with invention problems [7]. Therefore, they put forward the adaptive improvement of the classical TRIZ theory from different angles.

For the innovation practice of college students, it is difficult to use the theory and tools in TRIZ system to solve the specific problems encountered in the innovation process, which leads to the failure to effectively break through the boundary of inherent thinking, put forward the correct innovation strategy and thinking direction, and often lead to the deviation of the problem solving direction due to the preconceived thought.

In order to effectively play the advantages of TRIZ innovation theory in solving practical problems, and to meet the intuitive thinking habits of people solving problems, so as to determine the clue of innovation thinking simply, quickly and effectively, to get reasonable innovation strategies and find the root reasons hidden behind the problems, this paper puts forward intuitive, multi-dimensional. The TRIZ based TSD (time space direction) extension innovation model is easy to implement, and the basic process of problem analysis and solution is given.

II. Description Of Extension Innovation Model Of TSD

Although there are significant differences between TRIZ and Extenics in expression form and terminology, in fact, their corresponding problems can be transformed into a typical extensible basic problem, that is, the problem that one or more goals can't be achieved under the existing conditions [8]. Therefore, the problems faced by these two tools can be expressed by the following extension incompatible problem model.

$$P = G - L \tag{1}$$

In (1), the symbol "↑" indicates that under the condition of known method L, it is impossible to achieve the objective G which represents a certain (or a group of) subjective needs.

On the contrary, if the required target primitive G can be achieved by applying the current condition primitive L, it is indicated by the symbol "↓". According to the relevant methods of Extenics, the basic method to solve the incompatibility problem shown in (1) is to carry out some extension transformation on the target primitive G or the target primitive L, including the implication analysis of the target primitive to transform the original target, the extension transformation of the conditional primitive, and the simultaneous transformation of the target primitive and the conditional primitive.

For the problem to be solved as shown in (2), the solution to the innovative problem is essentially to find one or a group of extension transformations T, making the following formula true:

$$P' = G' \downarrow L' \tag{2}$$

In (2), the target primitive G' contains the extension transformation of the original target G, and the conditional primitive L' contains the extension transformation of the original condition L. However, in practical work, due to a lot of uncertainties in innovative work, the classical extension transformation method is difficult to operate. Therefore, according to the objective law of the object, this paper proposes the TSD (time space diffusion) extension transformation mode.

The universe (called "Yuzhou" in Chinese) is the general term of all space, time and matter. In other words, everything we can reach exists in the universe. "Yu" refers to the space dimension. "Zhou" refers to the dimension of time. That is to say, all the objects, events and behaviors we can recognize have their own spatial and temporal attributes.

For any problem, in addition to the two attributes of time dimension and space dimension, there may be totally different views in different directions in judging whether a thing or behavior is good or bad, true and false, right or wrong. It also has different significance and value for people of different identity types. In other words, the needs of the same person from different perspectives also have different values. For this reason, the existence value of a certain thing or behavior will change because of people's different perspectives. So when we are looking for a new way to solve the problem, we can put our thinking object into the three dimensions of time, space and direction for research. The change of any dimension condition can produce a new method and scheme. Each dimension can change different values, which can be continuous or discrete. In order to explain the problem more clearly, we can use formula (3) to describe the possible situations in the three dimensions of time, space and direction.

$$T_i = \left(t_i, s_j, d_k\right)^{\mathrm{T}}, \begin{cases} t_i \in \{t_1, t_2, \ldots, t_n\} \\ s_j \in \{s_1, s_2, \ldots, s_n\} \\ d_k \in \{d_1, d_2, \ldots, d_n\} \end{cases} \tag{3}$$

In (3), t_i is the scheme that may exist in time dimension, s_j is the possible scheme in spatial dimension, d_k is the possible scheme in the angle dimension.

For the contradiction problem described in (1), we assume that when there are enough alternatives n in each dimension, there will be:

$$P_i \in \left(P|T_i\right), \ \exists T_i = \left(t_i, s_j, d_k\right)^{\mathrm{T}}, \begin{cases} t_i \in \{t_1, t_2, \ldots, t_n\} \\ s_j \in \{s_1, s_2, \ldots, s_n\} \\ d_k \in \{d_1, d_2, \ldots, d_n\} \end{cases} \tag{4}$$

Make (5) be tenable:

$$P_i = G_i \downarrow L_i \tag{5}$$

Equation (5) is the consistent solution of the contradiction problem described in (1) through space-time angle transformation matching. In practice, the relative values of the three dimensions of time, space and direction are clear. In this way, when we fully consider the possibility of the three dimensions of time, space and direction, we can get enough different options. Therefore, it is easier to find thinking clues to solve problems and break through the blind area of inherent thinking, to overcome the deviation in the direction of solving problems caused by preconceived ideas.

TSD extension innovation model is a universal problem-solving mode of thinking, which is not only suitable for solving engineering and technical problems, but also suitable for solving interpersonal relations, social management and other aspects of the problem. However, because the model is a top-level logical thinking mode based on specific solutions to problems, when faced with specific practical problems, it naturally needs more specific innovative problem-solving methods at the operational level, so we think that we can organically combine the extension model of time-space angle with TRIZ model. In this way, we can easily find the breakthrough clue and direction through the TSD extension model when solving problems, and then determine the specific solution to the problem through TRIZ model.

III. TRIZ Problem Solving Process

Applying TRIZ analysis to problem solving is a very complex process. In order to illustrate the basic idea and general process of TRIZ analysis and problem solving, the process of TRIZ analysis and problem solving is simplified and sorted out [9], as shown in Fig. 1. The part of problem solving in TRIZ theory is relatively specific and easy to operate. Due to the limitation of space, it will not be repeated here. Compared with the tools of problem solving part, proper operation of the problem analysis part of TRIZ theory is the key to effectively transform real problems into TRIZ problems [10]. The problem analysis part mainly includes the ideal final solution analysis, system resource analysis, function analysis and causal chain analysis. The four parts interact and supplement each other to produce the problem solving model.

The ideal final solution, also known as IFR method, is the abbreviation of "Ideal Final Result" in English. The ideal final solution is a perfect solution to replace the limiting state with a symbolic way, similar to the way we model and solve equations. The ideal solution is a way of thinking that replaces the expected goal with the optimal model structure at the initial stage of solving the problem without considering the practical constraints. This method can effectively help people overcome the inertia of thinking and set the correct goal of solving problems. This link is also a process to transform real problems into TRIZ problems, which can be said to be the most difficult step to solve problems with the TRIZ theory [11].

Available system resources play an important role in innovative design. The closer the solution of the problem is to the ideal final solution (IFR), the more important the system resources are. The TRIZ theory holds that any system that does not have an ideal final solution should have system resources. Detailed analysis of the system resources necessary and profound understanding is necessary for the designer. System resources can be divided into internal resources and external resources. Internal resources refer to the resources existing in the region at the time of the conflict [12]. External resources refer to the resources existing outside the region at the time of the conflict. Internal resources and external resources can be divided into direct utilization resources, derived resources and differential resources [13].

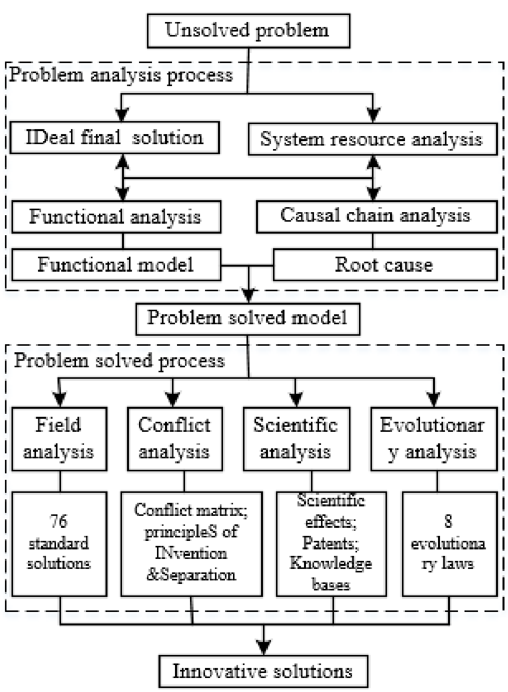

Fig. 1. simplified process of TRIZ analysis and problem solving

Function analysis is an important step in innovative design. To fully define all components related to the system and to identify the interaction between components, it is necessary to find out the main functions of the existing technical system and make it reach the optimal state [14]. And to find out the harmful, insufficient and excessive functions of the system, so as to find out the problems of the system and establish the function model.

Causal chain analysis is an analytical function used to identify major defects in a technical systems. Through the establishment of causal chain, the main defects and their underlying causes are linked [15]. For an initial defect, a series of causes can be obtained by asking why many times, which is called causal chain. In the unceasing inquiry, we discover the deep level reasons to the limits of physics, chemistry, biology geometry and many other fields.

IV. TRIZ-TSD Fusion Problem Analysis Process

When innovative designers encounter innovation problems, they should conduct function analysis, causal chain analysis and build function models based on the ideal solution and system resources in the absence of existing relevant information. It is difficult for qualitative analysis to intersect with quantitative analysis, and it is also difficult for analysis process to intersect with results, which will eventually lead to no solution or which will eventually lead to no solution or deviation of problem solving direction. Therefore, this paper combines the TSD extension model with the classical TRIZ theory, makes full use of the three-dimensional extension ability of TSD model, fully excavates the possible factors of each analysis module of the TRIZ, fully expands the amount of available information, and strives to achieve the intersection of qualitative and quantitative, process and result. The improved process of problem analysis is shown in Fig. 2.

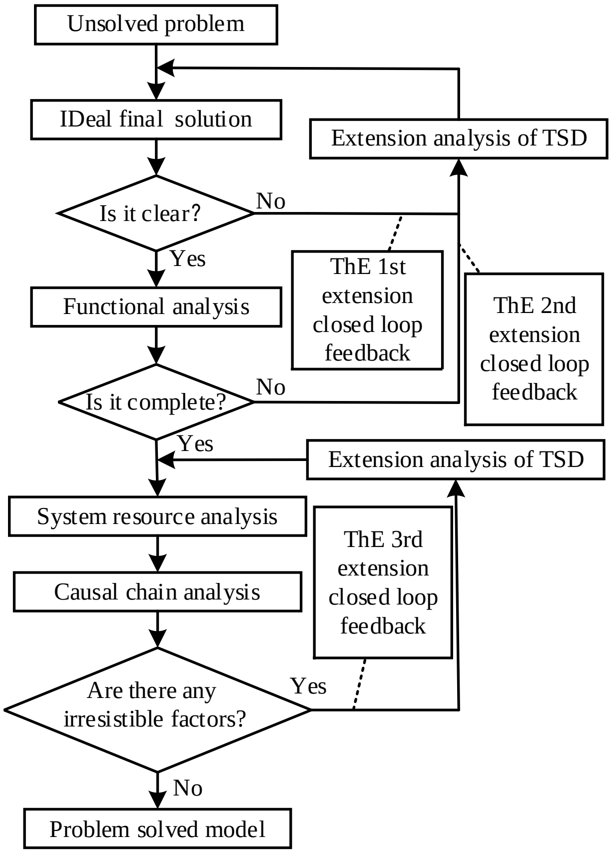

Fig. 2. flow chart of process of TRIZ-TSD fusion problem analysis

The extension model of TSD mainly conducts the extension analysis for the initial problems from three aspects, expands and decomposes the complex problem into several sub-problems, and finds the root causes of the problems by making full use of the transformation, subdivision and reorganization of the three dimensions of times, spaces and angles existing in the problems.

1) Starting from the orientation of the final ideal solution, the TSD extension analysis is introduced to form the first closed-loop feedback system of the first TSD extension analysis, so as to ensure the accuracy and clarity of the problem orientation;

2) We can introduce the second TSD extension analysis closed-loop feedback system according to the location of the final ideal solution. This system not only acts on the functional analysis part, but also takes into account the final ideal solution. The two are inseparable and mutually causal. And the two are considered comprehensively through the extension analysis of TSD.

3) After the function analysis, it enters the link of system resource analysis. Functional modeling and resource matching have entered into the analysis result of relatively specific problem solving, and the contradiction conflict and replication degree of the problem begin to increase dramatically. This link combines the causal chain analysis of TRIZ with the extension analysis of TSD, and makes efforts to play the rigor of causal chain analysis and the extension of analysis of TSD, so as to ensure the full exploitation of system resources and effectively meet the requirements of functional modeling.

After the problem analysis process of the above three links, the problem solved model will be finally obtained. At this point, the fused TRIZ analysis and identification process is completed, and then we can enter the TRIZ problem solving process as shown in Fig. 2, and we finally solve the problem. The purpose of fusion improvement is to make the analysis tools connect with each other, and avoid the isolated existence of analysis results, so as to identify problems efficiently and accurately.

V. Case Analysis And Verification

Taking "the intelligent wall planting system" as an example, this paper demonstrates and verifies the basic process and practical effect of TRIZ-TSD fusion innovation model in solving specific problems.

A. Questions raising

Many people like to plant flowers and plants in their rooms to add a touch of green. However, for young people working in big cities, the rented rooms are very small, and they often go on business trips, so it is difficult to realize this small wish in space and time.

B. The ideal final solution location

In this experiment, the contradiction between the final ideal solution and the present situation is as follows:

1) The contradiction of space is that the flower needs space, but the room has no space.

2) The time conflict is that I can't take care of the flowers but I want to raise them.

3) The contradiction of direction is the problem of wanting to raise flowers but not being able to raise them.

In view of such a contradiction, the first extension closed-loop in Fig. 2 is used for analysis. Starting from the location of the final ideal solution, TSD extension analysis is introduced to form the first closed-loop feedback system of TSD extension analysis, so as to make the problem location accurate and clear. The list of ideal solutions is shown in Table Ⅰ.

Table Ⅰ. Ideal final solution

Expandable dimensions	Present situation	Ideal final solution
space	There is not enough space for flower pots	There is enough space for flower pots
Time	If you leave for a long time, you can't grow flowers.	If you leave for a long time, your flowers can be taken care of.
Direction	I want to grow flowers, but I can't	You can grow flowers if you want to

C. Function analysis

According to the direct contradiction between the ideal solution and the current situation, the second extension closed-loop feedback system in Fig. 2 can be started, and the extension transformation can be carried out from three dimensions of space, time and direction respectively. From the space dimension, it is necessary to make up for the horizontal space with three-dimensional space. From the time dimension, the automatic remote control system is used to replace the artificial flower cultivation operation. From the dimension of direction, the sharing mode is used to make up for one's lack of experience in flower cultivation. The analysis results are shown in Table Ⅱ. We add two columns of extension mode and functional innovation on the basis of Table Ⅰ in Table Ⅱ. The extension method refers to the extension method of different TSDs applied in mapping ideal solutions of different dimensions to corresponding functions. In this link, the expansion advantages of the extension model of TSD are fully demonstrated, which can provide enough alternative ideas for innovation teams to effectively seek for the optimal solution. Functional innovation is the desired result of the step of functional analysis, and the function model can be constructed by the synthesis of all functions.

Table Ⅱ. Function list

Expandable dimensions	Present situation	Ideal final solution	Ways to expand	Function innovation
Space	There is not enough space for flower pots	There is enough space for flower pots	Spatial orientation. transformation There is no space in the plane, but there is space in the wall	The function of placing flowerpots on the wall
Time	If you leave for a long time, you can't grow flowers.	If you leave for a long time, your flowers can be taken care of.	Angle transformation. It can't grow flowers directly, but it can grow flowers indirectly	Flower raising or remote operation
Direction	I want to grow flowers, but I can't	You can grow flowers if you want to	Angle transformation You can't raise flowers by yourself, but you can raise them in other ways	Intelligent or shared flower cultivation

D. System resource analysis

The extension transformation and function innovation based on Table Ⅱ is equivalent to finding clear and detailed operational clues through TSD extension transformation, which can be easily expanded to the required resources. As shown in Table Ⅲ, the corresponding functional innovation maps out structural system, remote control system, automatic maintenance system, intelligent maintenance system and shared system respectively. Through causal chain analysis of the above five systems, we found that the industrial ecological chain required for the realization of the shared system is too complex, which is regarded as an irresistible factor. We find that it is not suitable to realize in the short term and it can be the future development direction we can explore based on the extension analysis of TSD, and can explore. There are no irresistible factors in other system resources. So we obtain the problem solving model corresponding to the ideal final solution, we achieve the goal of solving the problem through the realization of the above four systems. The concrete implementation process of the problem solving model can then be transferred to the TRIZ problem solving process.

Table Ⅲ. Function list

Expandable dimensions	Function innovation	System resources
space	The function of placing flowerpots on the wall	The flowerpot structure system that can utilize the wall space
Time	Flower raising or remote operation	Remote control system or automatic maintenance system
Direction	Intelligent or shared flower cultivation	Intelligent maintenance system or shared maintenance system

E. TRIZ problem solved process

Above process of analyzing the problems of the intelligent wall planting system, we further clarify the thinking and direction of the system development and development. The problem solving process that follows from this is relatively more specific and stylized, this paper only takes the development of flowerpot structure system that can utilize the wall space as an example to illustrate the basic process of problem solving based on the TRIZ theory.

In order to solve the fundamental problem of no place to place flowerpots, we can't place flowerpots on the wall directly. In other words, the improved parameter is the structural stability, while the deteriorating parameter is the operability. Therefore, referring to the conflict matrix, the corresponding invention principle of the TRIZ are No. 35 (Parameter variation), No. 24 (Intermediates), No. 30 (Flexible shell or membrane), and No. 18 (Vibration). We selected the optimal scheme 24 (Intermediary), we chose the flowerpot shelf installed on the blank wall is made of verified materials. The innovative object is shown in Fig. 3.

The innovative object adopts three-dimensional structure, which fully overcomes the problem of limited floor space of the room. According to a similar way, the intelligent control system of other systems of "the intelligent wall planting system" is developed, which can solve the problem that no one takes care of the flowers during long-term business trip. At the same time, because of the intelligent control system, remote plant maintenance can be realized, which provides the necessary basis for sharing maintenance technology and information exchange. The complete work is shown in Fig. 3.

Fig. 3. physical picture of innovative works

VI. Conclusion

Through the research and verification of TRIZ-TSD extension problem solving model, we draw the following conclusions.

1) In TRIZ-TSD extension problem-solving model, the orientation of ideal solution and function analysis method can help innovative designers overcome the fixed mode of thinking, find the core and key problems at the macro and micro levels, and achieve the purpose of accurately defining the core and essence of the problem;

2) In TRIZ-TSD extension problem solving model, the system resource analysis method is more convenient to explore and identify hidden available resources, which makes it more suitable for beginners to use in practical innovation;

3) In TRIZ-TSD extension problem-solving model, the problem-solving process is more in line with people's intuitive thinking habit of problem-solving. It is an innovative thinking strategy. It can timely and accurately redefine the problem, lock in the key factors that affect the occurrence of the problem, and finally realize the identification of the core key problems.

VII. Prospect

TRIZ-TSD innovation model and process still have a lot of room for improvement and development.

1) TRIZ-TSD model makes TRIZ innovation theory more convenient for practical operation through the extension of space-time angle. However, the current research is still limited to the macro exploration of mode and thinking, and more innovative designers are required to participate. The next step is to further carry out the mathematical modeling of TRIZ-TSD theory, so as to lay a theoretical foundation for the programmed innovation of artificial intelligence.

2) There are not many practical cases of TRIZ-TSD model at present. If we can establish a rich and standard TRIZ-TSD innovation case base, it will provide data sources for big data innovation design.

3) In addition to the application of TRIZ-TSD model in the field of Engineering Science and technology innovation, it can also be further applied in other fields such as management, humanities, social sciences, economy and so on.

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