Method of Design Transformer Based on Multiple Scenario

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Abstract. Transformer are available in multiple scenarios, transformation can improve the adaptability of the product. The systematic innovative design method of the transformation is helpful to the realization of the automatic invention. Three dimensions of space, time and conditions are used to analyze the scenarios of the product. Draw scenario - need - function hierarchical diagrams to analyze the specific functions of each scenario and the relationship between them. Determine the form of the scenario specific function through four rules. The theory is verified by the case of bridge erecting machine.

Keywords: Transformation, Scenario Analysis, Product Design

1 Introduction

Many products were used in a single scenario, resulting waste of resources, Transformable products are designed to meet the needs of users in different scenarios. Transformation is the act of changing state in order to facilitate new, or enhance an existing functionality [1]. Scenario analysis is a method to generate the future Scenario by means of hypothesis, prediction and simulation, and analyze its influence on the target [2]. Existing products can provide their expected functionality in known scenario. By analyzing the potential use scenario of existing products, the user needs of the product in the potential scenario are obtained, Thus, the different function should be provided in different scenario. A product provides function in a given scenario as a scene function, the scene functions of different scenarios are different. If a product or technical system can meet the user's needs in different scenarios, the product or technical system will have a high adaptability. Functional integration enables the product to meet user needs in each usage scenario. However, the function provided by the product in a given scenario may not be needed in another scenario, and simple functional integration can result in the product's functional redundancy.

Vikram Singh defines ‘transformation’ is the act of changing state in order to facilitate new, or enhance an existing functionality. The principle of product innovation through ‘transformation’ has been studied. expand/collapse, expose/cover, fuse/divide

Three transformation principles are obtained by analyzing a large number of cases. A number of transformation facilitators such as ‘Common core structure’ and ‘composite’ are summarized. It lays the foundation for the theory of transformation design [1]. Vikram Singh designed the transformation products through four steps, including understanding generalized scenario, creating objectives, gathering customer needs and generating capabilities. Then, choose similar needs and capabilities to find out which objectives are appropriate for shaping the transformation design solution. Considering the needs and capabilities of these objectives, the product form is extracted [3]. If these separated states are not required at the same time, the transformation design method can be used. The concept design is generated by means of transformation principle, transformation facilitator or T card. For a more comprehensive discovery of the potential use scenario of the product. This article adopts the method of scenario analysis to help designer to determine which function should be added to the existing product and using transformation method to complete the final design. This paper proposes find out the potential scenarios of products from the three dimensions of time, space and conditions. Scenario - need - function hierarchical diagram can help designer to better understand the functions required for each scenario.

2 Multi-scenarios analysis to determine product function

Users need products to provide different functions in different scenarios. If a single function product is manufactured to meet the needs of users in a single scenario, the resources will be wasted. Users have different requirements for the product in each scenario. Analyze the potential scenario of each product, and obtain the user's needs in each scenario, and obtain the function that the product should provide under each scenario through needs analysis(see **Fig. 1**).

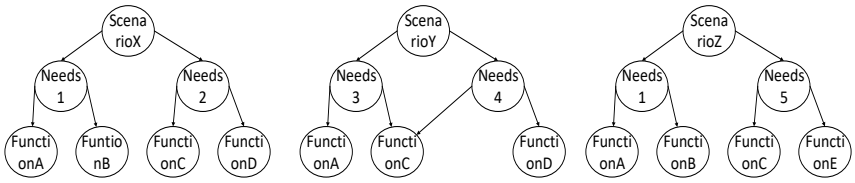


Fig. 1. Hierarchical approach

Transformer present different states in different scenarios to perform different functions. In this paper, the scenario is divided into three dimensions: space, time and condition. There is a change in the three dimensions of the scenario of the product, and the scenario of the product changes.

2.1 Space dimension

Users have different needs in different space dimension, the product needs to provide different functions to meet the needs of users in this space dimension. For example, as

shown in Fig.2, the stroller needs a certain amount of space to keep the baby comfortable outside, while in the car the user wants it to be infinitesimally small and does not occupy any space(see **Fig. 2**). The scenario of the stroller in the outside and in the car is different in space dimensions.

Fig. 2. Pockit stroller [4]

2.2 Time dimension

The user's requirements change over time，the user needs the function provided by the product to change as well. See **Fig. 3** for the three-wheeled bicycle. When the user can't master the bicycle balance, the rear wheel of the bicycle is "A". Over time, users have become more adept at cycling, the rear wheel of the bicycle is "H". When the user wants to ride on a high speed, the rear wheel of the bicycle is "V".

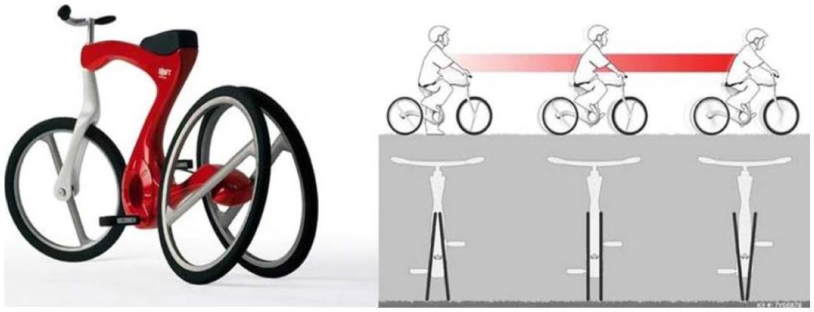


Fig. 3. SHIFT's wheels shift as the child gains momentum [5]

2.3 Condition dimension

In the same time and space, the condition is different, the product use scenario is different. As shown in **Fig. 4**, the puffers can inhale and expand to scare off enemies when they are in danger. Danger and safety are different in terms of conditions.

Fig. 4. pufferfishes [6]

The three dimensions of the scenario are represented as {Si, Tj, Ck}.

S, T, C represent space, time and conditions. j, k, l=1,2,3……

For example, the use scenario is $\{S_1, T_1, C_1\}$ when infants in the stroller. The scenario is $\{S_2, T_1, C_1\}$ when the stroller in the car. The different dimensions of the two scenarios are space, so $S_1 \neq S_2$.There is a change in the use scenario of a product in three dimensions: space, time, and condition. In the process of designing the transformer, the possibility of each dimension of the scenario should be taken into account. There are m kinds of space, n kinds of time and p kinds of conditions. So there is $m \times n \times p$ kinds of use scenarios of this product. The following matrix is shown.

$$\begin{array}{l} \text{Scen 1} \\ \text{Scen 2} \\ \text{Scen 3} \\ \cdots\cdots \\ \text{Scen x} \end{array} \begin{pmatrix} S_1 & T_1 & C_1 \\ S_2 & T_1 & C_1 \\ S_2 & T_2 & C_1 \\ \vdots & \vdots & \vdots \\ S_m & T_n & C_p \end{pmatrix}$$

After determining all the scenarios, analyze the user needs in each scenario in turn. If the user needs are same in both situations, the two scenarios are homomorphic scenario. Homomorphic scenario just need one state to perform function. Such as Scen 1 and Scen 2 in the above matrix, after the demand analysis, we found that the user needs are the same in both situations, although $S1 \neq S2$.So the two scenario just need one state, Called Scen 1=Scen 2.

The functions that are needed in each scenario are called common functions of scenario. Specific functions of scenario are functions that are not required for all scenarios. A state of the product corresponds to a usage scenario. The specific function of a scenario is not needed in other scenario, Therefore, the structure that only performs this function can be eliminated in other scenario.

Four rules for determining how the scenario specific function existence:

1. If the structure that provides the scenario specific function can transform to another state to provides the function of the target scenario, then perform the transformation.

2. If the structure that provides the scenario specific function can transform to another state to provides the function of the target scenario, but it can be hidden, then hide it.

3. If the structure providing this function cannot be transformed to provide function for other scenario, and the structure does not affect the product's ability to provide other functions in other scenario, then preserve its structure.

4. If the structure providing this function cannot be transformed to provide function for other scenario, and the structure affects the product to provide other functions in other scenario, then take down the structure in other scenario.

3 case study

As a highly efficient special bridge construction equipment for erecting prefabricated beams throughout the construction of railway lines and highways, the bridge erecting machine is an indispensable main mechanical equipment in a large number of bridge constructions[7,8].With the rapid development of China’s railway and highway construction, the demand for bridge erection machines is increasing, the performance of the bridge erecting machines is constantly improving, and the types are also increasing[9].The structure of the bridge erecting machine generally includes the main beam of the bridge erecting machine, the crane beam crane on the main beam, and the legs of the bridge erecting machine. According to the different types of the bridge erecting machine, some bridge erecting machine have guide beams. In addition to the above structure, the beam type bridge erecting machine also has a lower guide beam, and the double guide beam type bridge erecting machine has a structure such as a lower guide beam and a cantilever beam [10-14]. First, the existing working process of bridge erecting machine is introduced, and then a new idea of transformation is put forward.

Working steps are as follows [15]:

Step 1: The bridge erecting machine is in a ready state（see **Fig. 5**）.

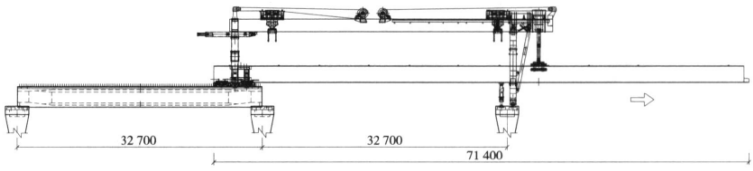


Fig. 5. Transport beam

Step 2: Transporting the beam into the beam and converting the machine to the bridge support state. The beam is connected to the lower guide beam and fed to the beam（see **Fig. 6**）.

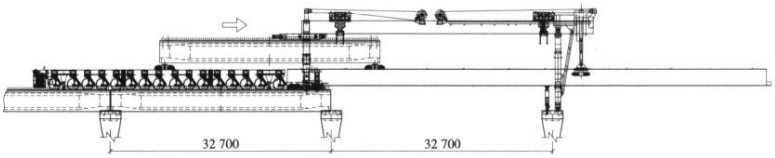


Fig. 6. Feed beam

Step 3: Feeding the beam in place, and the rear leg is lowered and erected. The front and rear hoisting trolleys lift the box girder synchronously, the truss gondolas are returned to the girder transport truck, and the girder transport car is loaded into the girder. Take the front leg and lift the front of the lower guide beam. The lower guide beam retreats under the power of the idler.

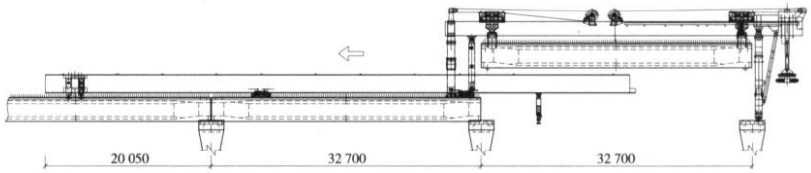


Fig. 7. Lifting beam

Step 4: The lower guide beam continues to move backwards while its front leg moves forward along the lower guide beam. After moving to the front point of the lower guide beam, turn it upwards. The forward guide point of the lower guide beam is moved to the top of the box girder to allow the space to exit the girder, the drop beam is in place.

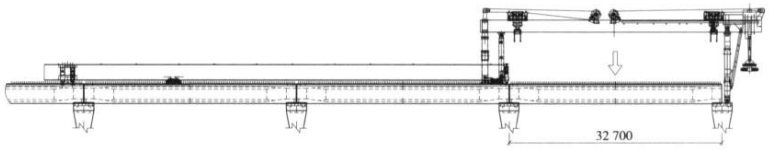


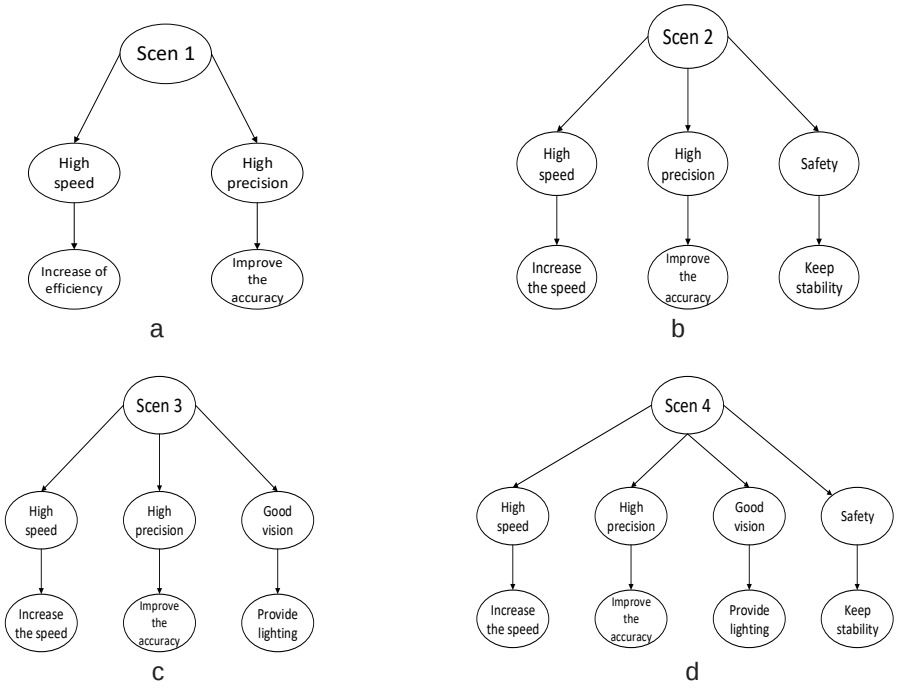
Fig. 8. Fall beam

The use scenario of the bridge erecting machine in the spatial dimension is divided into S1: bridge operation space and S2: storage space. The time dimension is divided into T1: daytime work and T2: night work. The conditional dimension is divided into C1: operation in normal weather and C2: operation extreme weather. Therefore, there are eight scenarios in which the bridge erecting machine was used. Normal weather work during the day: Scen 1（S1 T1 C1）.Extreme weather work during the day: Scen 2（S1 T1 C2）.Normal weather work during the night: Scen 3（S1 T2 C1）.Extreme weather work during the night: Scen 4（S1 T2 C2）.Normal weather storage during the day: Scen 5（S2 T1 C1）.Extreme weather storage during the day: Scen 6（S2 T1 C2）.Normal weather storage during the night: Scen 7（S2 T2

C1）.Extreme weather storage during the night: Scen 8（S2 T2 C2）.The scenario matrix of the bridge erecting machine is followed:

$$\begin{array}{l}\text{Scen 1}\\ \text{Scen 2}\\ \text{Scen 3}\\ \text{Scen 4}\\ \text{Scen 5}\\ \text{Scen 6}\\ \text{Scen 7}\\ \text{Scen 8}\end{array}\begin{pmatrix} S_1 & T_1 & C_1 \\ S_1 & T_1 & C_2 \\ S_1 & T_2 & C_1 \\ S_1 & T_2 & C_2 \\ S_2 & T_1 & C_1 \\ S_2 & T_1 & C_2 \\ S_2 & T_2 & C_1 \\ S_2 & T_2 & C_2 \end{pmatrix}$$

Scenario -need - function hierarchical diagram is shown in Fig.9:



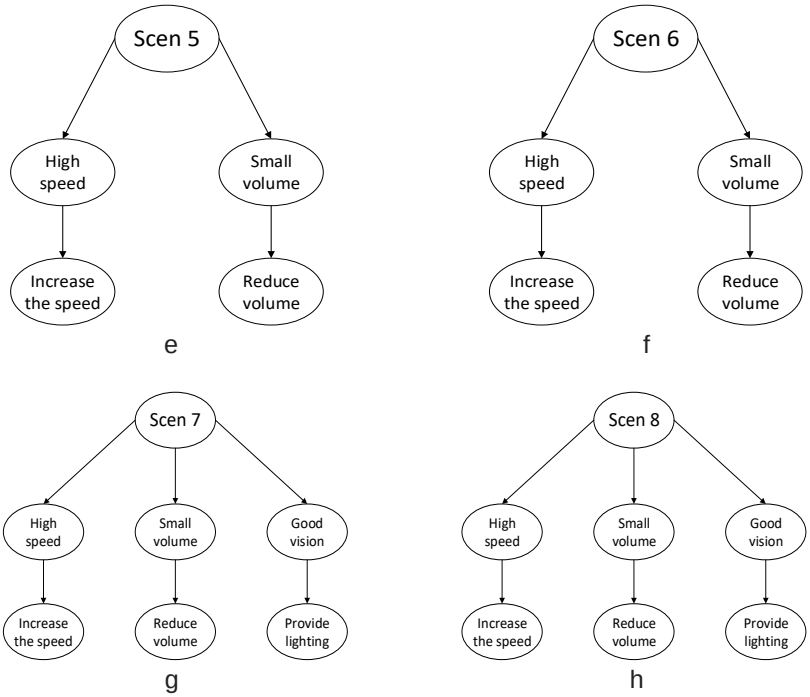


Fig. 9. Scenario - need - function hierarchical diagrams of bridge erecting machine

The needs and functions of Scen 5, Scen 6 and Scen 7, Scen 8 of the bridge erecting machine are the same, so the Scen 5 and the Scen 6 are homomorphic scenario; the Scen 7 and the Scen 8 are homomorphic scenario. The final product of the bridge erecting machine can meet six different scenarios.

As the four rules mentioned in the previous section, provide lighting that only needs searchlights, do not affect other functions, and cannot change the structure to provide other functions. Therefore, lighting functions need not be eliminated in any scenario.

To keep stability does not require transformation of the system, just need the bridge erecting machine frame and guide beams with sufficient strength are required.

It is necessary to reduce volume when storing. Select the principle of expand/collapse to implement this function [1]. The solution is make the connection of the guide beams and the frame be flexible. The rack is folded by transforming the structure to facilitate storage.

4 conclusion

The products that form transformation products can serve the users in multiple scenarios greatly improve the adaptability of product. Divide the product's use scenario into three dimensions: space, time, and condition, and search for potential use scenarios

for products more comprehensively. Through the scenario-need-function Hierarchical graph, the degree of relevance of the function in each scenario is more intuitively seen, and the four rules determine how the scenario specific function existence.

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References

1. Singh, Vikramjit, et al. "Innovations in design through transformation: A fundamental study of transformation principles." Journal of Mechanical Design ,131.8,081010 (2009)
2. Wei Lou. Scenario analysis: theory and method. Social Sciences Aacademic Press, China(2012)
3. Singh V, Walther B, Krager J, et al. Design for transformation: Theory, method and application, Proceedings of the ASME International Design Engineering Technical Conference & Computers and Information in Engineering Conference,447-459, Las Vegas, NV(2007)
4. New Tricycle Morphs Into Bike on the Go, https://www.livescience.com/227-tricycle-morphs-bike.html, last accessed 2018/03/21.
5. POCKIT 2A-Q109RB,https://www.haohaizi.com/product-6332.html,last accessed 2018/03/21.
6. Pufferfish-es,https://en.wikipedia.org/wiki/Tetraodontidae#/media/File:Arothron_meleagris_by_NPS_1.jpg, last accessed 2018/03/21.
7. Chun Liu. China High-speed Railway Bridge Erecting Equipments Industry Research and Forecast, Construction Machinery Technology & Management2(015),56-60(2009)
8. Xingfeng Cheng. China Bridge Machinery Manufacturing Industry Status and Development Strategy. Railway Standard Design3,14-16(2002)
9. Qianya Mao, Wentao Yu. Current Status and Prospects of Bridge Erection Machines at Domestic and Foreign. SCIENCE & TECHNOLOGY INFORMATION7,87-89(2008)
10. Hao Chen, Zhihua Zhang. DF900D Guide Beam Type Fixed Point Crane. Railway Standard Design3,10-13(2008)
11. Jingshi Tang, Bridge and Tunnel Engineering and Mechanical Selection. China Railway Publishing House, Beijing(2001)
12. Lanxin Hou. Analysis of JQ900 Type Beam Guided by Simple Support Box Girder. Enterprise Technology Development8,30-32(2008)
13. Kaiyan Li. Integrated Rack and Bridge Erection Technology and Process, China Railway Publishing House, Beijing(2002)
14. Zhaohong Li, Jiawu liu. Study on 900 t Machine Passing Box Beam Girder over Tunnel on Passenger Dedicated Line, Railway Standard Design9,5-7(2007)
15. Wentao Yu, Zemin Xue, Caikui Hong. Characteristics and Operational Process of 900t Tunneling Machine Passing over Passenger Dedicated Lines, Railway Standard Design11,33-38 (2007).