Title:
Product innovation design method based on scenario

Authors:
Limeng Liu, liulimvp@163.com, Hebei Vocational University of Technology and Engineering, Hebei Special Vehicle Modification Technology
Pengcheng Sheng, 570463334@qq.com, Hebei Vocational University of Technology and Engineering
Jingang Ma, majg2618@126.com, Hebei Vocational University of Technology and Engineering
Fei Wang, 21724339@qq.com, Hebei Institute of Machinery & Electricity,
Runhua Tan, rhtanhebut@163.com, Hebei University of Technology, National Engineering research Center for Technological Innovation Method and Tool

Keywords:
Innovative Design; Scenario Condition; Scenario Element; Operation Rules; Case Retrieval

DOI: 10.14733/cadconfP.2023.111-116

Introduction:
Demand-driven innovation is one of the most widely used innovation approaches by companies. Traditional methods such as QFD-based methods, Kano model-based model, innovation techniques in TRIZ, and ethnography have been proposed, but these methods suffer from complex and time-consuming information acquisition, ambiguous processes, and unclear expressions of customer wishes and demand attributes in their application [1]. In recent years, "scenarios", which emphasize better thinking about the future from the present, have been introduced into the field of product design [2]. Some achievements about scenario based design have been gained. SCHUH et al [4] proposed a method to determine the characteristics of future products by using scenario simulation and planning. RANDT [3] obtained the expectation of future user demand under uncertainty by considering the choice of future scenarios to derive robust design requirements. Zhang et al [5] proposed a product innovation design process in which environmental profile transformation guides scenario analysis. The above researches have extended the application of scenarios in innovation design, but there are still problems with the formulation of scenarios, unclear reasoning processes, and the overall process is complex and abstract.

This paper explores a new approach to introduce scenarios into the field of product innovation design. First, a scenario knowledge representation is proposed, then scenario operation rules guided by requirement evolution laws are introduced to construct new scenario conditions. To better utilize innovation opportunities to obtain innovation solutions, an effect search process and a heuristic case-by-case search method is proposed by matching effect and scenario elements, which is used to obtain valuable innovative product design solutions adapted to new scenario conditions by analogy. Finally, a scenario-based innovative design process is proposed. The innovative design of the Chinese medicinal materials (CMMs) dispensing machine verifies the proposed method.

Main Idea:
Product scenario knowledge and representation

The objective things and their states that play a key role in the scenario evolution process are called scenario elements and are characterized as

$$E=(N,C_n,V_n)$$

Where N represents the concept name of the scenario element; C_n represents the nth feature of the scenario element; V_n denotes the state index of the nth feature.

Scenario elements can be divided into three categories: product-related elements (*Ep*), user-related elements (*Eu*), and environment related elements (*Ee*). Among them, there is a type of scenario elements that marks the completion of the main design purpose called core scenario elements and can be recorded as *Ec*. The scenario condition is the initial state of the product scenario without the product, which reflects the initial condition of the product application.

The external interaction behavior EB and internal inter-agency operation behavior IE of the expected product scenario within a typical work cycle are analyzed, and a scenario behavior chain according to the causal sequence can be constructed as shown in Fig. 1 to express the evolution process of the scenario. Each scenario behavior has corresponding pre-order and post-order key scenario elements.

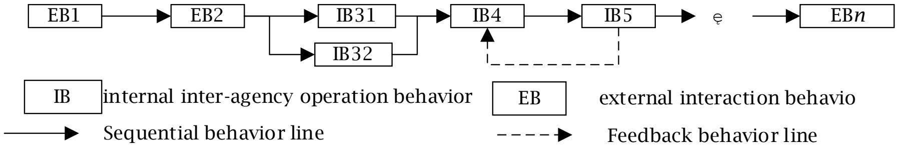

Fig. 1: Scenario behavior chain of product action.

Exploring new scenario conditions

Through the operation of the original scenario elements, reliable and valuable scenario conditions can be provided for designers. The basic scenario element is set as $Ea = [N_a, C_a, V_a]$, and the following five scenario element operation rules are summarized:

Rules	Resume	Operation process	Remarks
Rule1	Expansion of multiple features of the same type of an element	$Ea \rightarrow E_a = \begin{bmatrix} N_a, & C_a, & V_a \\ & C_b, & V_b \\ & \cdots & \cdots \end{bmatrix}$	Remark 1: There is a correlation function between C_a and C_b or/and V_a and V_b. Or there is an inclusion relationship between E_a and E_b .
Rule2	Convert to an element with the same characteristics	$E_a \rightarrow E_b=[N_b, C_a, V_a]$	
Rule3	resetting status indicators of the element	$E_a \rightarrow E_b=[N_b, C_a, V_a]$	
Rule4	Convert to an scenario element with relevant characteristics	$E_a \rightarrow E_b=[N_b, C_a, V_a]$ (Remark1)	
Rule5	Delete or add elements	$E_a \rightarrow E_b=[N_b, C_a, V_a]$	

Tab. 1: Operation rules of scenario elements.

To obtain valuable design demands through operation strategies of scenario elements, an effective relationship between the scenario and demand evolution law is established. The process is as follows

The operational scenario elements Ea= [*Nax*, *Tax*, *Vax*] → is linked to C (from 1.1 to 5) → is linked to Rule (from 1 to 5). The operational mapping process is summarized as shown in Fig. 2.

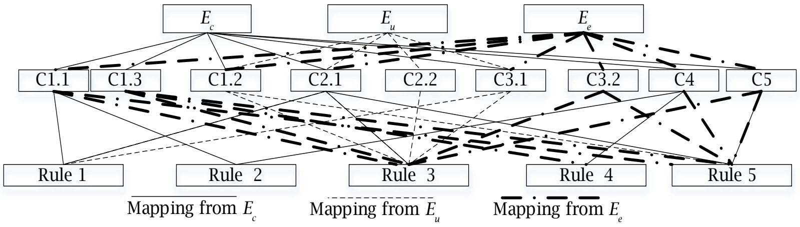

Fig. 2: Mapping process of scenario element operation based on demand evolution law.

In which, C is the characteristics of demand evolution law summarized in TRIZ: C1.1 Improve quality, C1.2 Reduce production time, C1.3 Reduce side effects, C2.1 Increase adaptability, C2.2 Reduce manpower, C3.1 Improve coordination, C3.2 Easy operation, C4 Multifunction, C5 Improve pertinence.

Scenario-oriented case retrieval

The scenario variables in the new scenario conditions are brought into the units of the original scenario behavior, which leads to abnormal evolution. To complete the intended scenario, the product design solution needs to be reconstructed, and a scenario-oriented case retrieval process is proposed, as shown in Fig. 4.

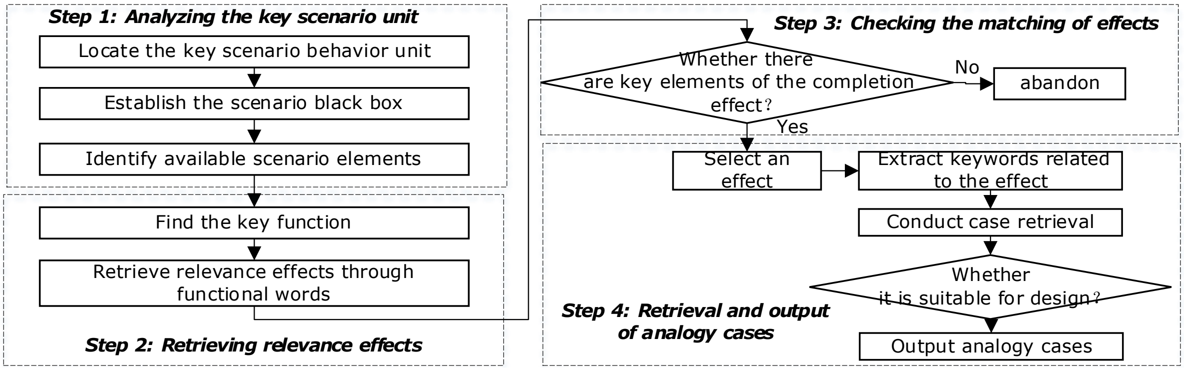

Fig. 3: Scenario-oriented case retrieval process.

Scenario-based product innovation design process model

The proposed product innovation design process based on scenario consists of the following six steps:

Step 1: Identifying known elements in the future product scenario typically includes some initial and ending scenario elements, articulate major elements, key feature attributes, and feature state changes.

Step 2: Based on the design requirements, the existing typical products are selected as prototypes through market research or patent search, and product scenario analysis is performed to obtain information on typical scenario conditions and the scenario evolution process.

Step 3: According to the process described in Section 2.2, the key scenario elements that may exist in the future product scenario can be got through the scenario element operation mapping process. Then the potential scenario conditions in the future can be obtained by restructuring relevant elements. It requires that products need to adapt to new conditions, thus generating new innovation opportunities.

Step 4: Based on the key the scenario variables are brought into the original scenario behavior chain for analysis, and the associated scenario behavior units are located. Then the appropriate analogy cases can be retrieved by applying the process in Section 2.3.

Step 5: A method based on value engineering can be introduced to optimize and select the appropriate innovation scheme through the evaluation of key indicators of each scheme by experts.

<u>Case Study:</u>

The proposed process is applied to the innovative design of a CMMs dispensing machine as follows.

1) The dominant demand is “dispensing CMMs”. The key scenario elements are

$$Eci=\begin{bmatrix} CMMs, & Position, & Medicine\ box \\ & Weight, & Not\ measured \end{bmatrix}; Ece=\begin{bmatrix} CMMs, & Position, & Pharmaceutical\ bag \\ & Weight, & The\ stated\ dose \end{bmatrix}$$

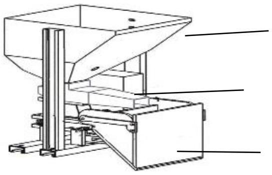

Fig. 4: A vibrating blanking type CMMs dispensing equipment.

2) An CMMs dispensing machine is selected as the prototype product shown in Fig. 4 after analyzing the related patents and devices, which relies on gravity and vibration to realize CMMs transportation.

The typical action place of the prototype product is indoors, such as in pharmacies, hospitals, etc. In the expected scenario evolution, the initial scenario conditions include P_0Ec_1= [*CMMs*, Physical shape, *Small and regular granules*], P_0Ee_1= [*Indoor*, *State*, *Normal temperature and pressure*], P_0Ee_2= [*Socket*, *State*, *Presence of electricity*], P_0Eu_1= [*Users*, *Characteristics*, *The able-bodied*]. The scenario behavior chain of the prototype product is shown in Fig. 5.

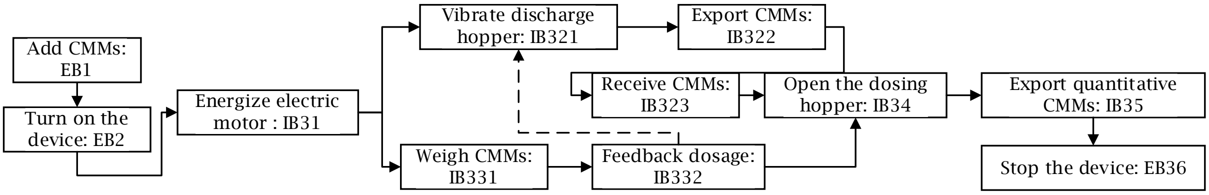

Fig. 5: The scenario behavior chain of the prototype product.

3) *Ec* can be selected for operation. The prototype product can only be configured with relatively small and regular granular CMMs. If it evolves in the direction of C2.1increase adaptability, P_1Ec_1= [*CMMs*, *Physical shape*, *Granular and powdered*] can be obtained by applying Rule1 operation. If it evolves to C1.2 reduce production time, Rule5 is used to add the dose information display to obtain the new scenario element P_2Ece_1 = [*CMMs*, *status, quantitative continuous multiple bags*].

Ee can be selected for operation, P_3Ee_2 can evolve towards C2.1 increase applicability, and Rlue5 operation can be applied to delete power socket P_0Ee_2. Similarly, a series of new scenario elements such as $P4_4Eu_1$= [*user*, *ingredient*, *Chinese medicine trader*], P_5Eu_2= [*user*, *degree of participation*, *little or no*] can also be obtained through similar steps.

Multiple new scenario conditions can be built, P_1Ec_1 and P_2Ece_1 are selected for further design which means the powder or granular CMMs can be quantitatively configured several times in succession.

4) The strong relevant behavior of P1Ec1 is “Export CMMs: IB322” by introducing P1Ec1 into the scenario behavior chain. The key function action of IB322 can be abstracted as “move solid”, there are also air, gravity, electricity, rotary power, and other resources in the scenario. The pre-order scenario elements of IB322 are [CMMs, location, medicine box], [energy, type, kinetic energy and electric energy], and the post-order scenario elements are [CMMs, state, falling], [energy, type, kinetic energy and electric energy]. There are also air, pressure, gravity, electricity, rotary power and other resources in the scenario.

A knowledge base called “effect knowledge base for function realization of different forms of matter” [6] is used to search for available effects: vibration, gravity, Pascal’s law, Bernoulli effect, spiral principle, etc. Due to the existence of pressure and air, the Pascal’s effect can be selected. "air suction" can be extracted as the key word from the Pascal’s effect, main function can be abstract as” move object”. Then, using (“air suction” and “move object") as the retrieval formulas for patent retrieval, a suitable case is selected as shown in Fig. 6(a), then an innovation scheme 1 is got through analogy improvement as shown in Fig. 6(b). Similarly, by selecting spiral principle, and applying "rotate" and “move object” to retrieve, scheme 2 can be obtained as shown in Fig. 7(a).

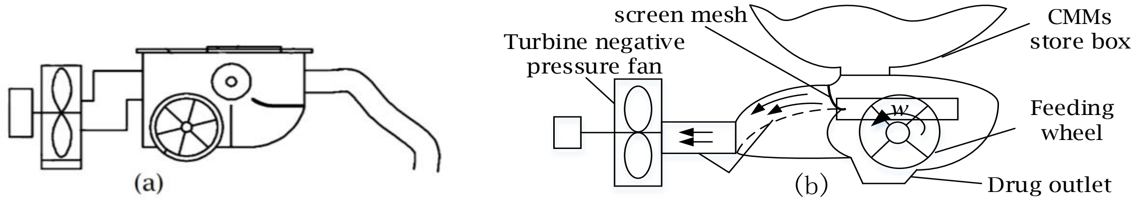

Fig. 6: (a) Schematic diagram of the negative pressure jujube picker, (b) Schematic diagram of the negative pressure type CMMs transport mechanism.

After expert analysis, the indicators of speed, accuracy, complexity, reliability, novelty, and applicability of the original solution and the two new solutions are assigned and evaluated, the screw feeding type CMMs transport mechanism has higher advantages.

5) A new CMMs dispensing machine can be obtained by integrating and optimizing the schemes as shown in Fig. 7(b). The experiment shows that the new scheme can realize the rapid quantitative configuration of CMMs, the output speed and accuracy are better than the prototype product.

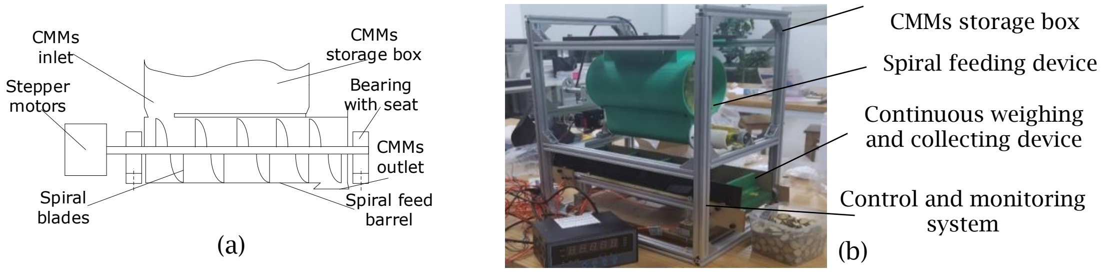

Fig. 7: (a) Schematic diagram of the screw feeding type CMMs transport mechanism, (b) Physical prototype of the new CMMs dispensing machine.

<u>Method Evaluation</u>

Our method was compared with four existing methods. Experts were invited to rate the applicability, number, novelty, and commercialization of the innovative results that resulted from the use of the different methods. The results were: Proposed method＞Kano model-based method＞TRIZ-based method＞QFD-based method＞Ethnography. Thus, the proposed method proves to be superior

<u>Conclusions:</u>

The representation of scenario and the steps of constructing new scenario conditions are proposed, and the heuristic case search method based on the retrieval of effects and the matching of the scenario elements is introduced. A product innovation design based on scenario is put forward. Further work will apply the method to different cases for improvement.

<u>Acknowledgements.</u>

This research is sponsored by National key research and development program (2017YFB0102500)), Science and Technology Research Project of Colleges and Universities of Hebei Province (QN2019094, ZD2021338)

<u>References:</u>

[1] Lee, C.H.; Chen, C.H.; Lee, Y.C.: Customer requirement-driven design method and computer-aided design system for supporting service innovation conceptualization handling. Advanced Engineering Informatics, 2020, 45: 101117. https://doi.org/10.1016/j.aei.2020.101117

[2] Lee, S.M.; Trimi S.: Innovation for creating a smart future, Journal of Innovation & Knowledge, 3(1), 2018, 1-8. https://doi.org/10.1016/j.jik.2016.11.001

[3] Randt, N.P.: An approach to product development with scenario planning: the case of aircraft design. Futures, 71, 2015, 11-28. https://doi.org/10.1016/j.futures.2015.06.001

[4] Schuh G.; Schultze W.; Schiffer M.: Scenario-based determination of product feature uncertainties for robust product architectures, Production Engineering, 8(3), 2014, 383-395. https://doi.org/10.1007/s11740-014-0532-4

[5] Zhang H.G.; Li Y.C.; Gao S.S.: Product technology foresight method guided by environmental profile transformation scenario analysis. Machine Design & Research, 37(02), 2021, 163-167+172. https://doi.org/10.13952/j.cnki.jofmdr.2021.0076

[6] Zhao, M.; Zhang, W.; Wang, G.: TRIZ enhancement and practical applications, China Machine Press, Beijing, BJ, 2015.