Research and application of TRIZ theory in the field of service robots

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Abstract. Service robots in China are in the rapid development, with an increasing proportion in the field of robotics, but there is still a big gap with other developed countries in the core technology, systematic innovative design theory guidance is particularly important. Therefore, FEPAM model (function-effect-process-action-mechanism model) and TRIZ (Teoriya Resheniya Izobreatatelskih Zadatch) were integrated. First of all, through the analysis of the market demand and existing products, the working mechanism is decided. According to the mechanism, the process action process is conceived. Finally, the executive mechanism that needs to be improved is determined. By establishing the Su-field type and adopting the corresponding standard solution, the product function innovation is realized. The proposed method is applied to a delivery robot, and the problem of inconvenient man-machine operation is solved quickly. The results show that the proposed model can improve the solving speed of the Su-field model, enrich the standard solution model, and provide a new idea for the future development of Su-field model.

1. Introduction

Since the 1980s, China started the research in the technology of service robot, many breakthroughs have been achieved in the development of service robot [1]. However, compared with developed countries, there are still many gaps in the core technology. At present, the main reason for the lack of innovation ability in the field of service robots in China is the low level of product design, especially the lack of innovative design methods and theoretical guidance in this field. Therefore, it is very important to use systematic and advanced innovative design methods to guide the design.

TRIZ theory is a method of systematic problem solving by former Soviet Union expert Altshuler and his team through analysing a large number of patents [2], successfully revealing the principles and laws of design creation. Compared with other commonly used innovation methods, it has better universal applicability. It is based on scientific and technological methods. The most important thing is that TRIZ involves a larger scope and has great potential for innovation in the field of technology.

Substance-field model is a commonly used problem analysis model in TRIZ theory. It uses special symbols to express problems and uses graphic tools to simplify complex systems [3]. Altshuler proposed that a complex engineering system can be split into multiple simple engineering systems. A complete engineering system must have three elements in order to work normally. These three elements are, acting substance $S_1$, being acted substance $S_2$ and the field $F$ of the interaction between substances [4]. The organic combination and mutual interaction of the three elements constitute a function. When the system lacks related elements, or the interaction between the elements produces is...
harmful effects, it is necessary to introduce external elements or improve the system to make the system achieve the desired effect.

The function analysis of the Su-field model is insufficient and lacks pertinence [5], and it is unable to find the place that needs innovation and improvement in time. Therefore, the research on the Su-field model is divided into the improvement of the model and the integration with other theories. The FEPAM model [6] in mechanism is combined with the Su-field model, and the practicability of the model is verified by taking the distribution robot as an example.

2. Integrating FEPAM Model with Su-field Model

In the process of mechanism design, the lack of complete innovative design ideas often slows down the solution process, affects the product development time, prolongs the life cycle of product design, and makes enterprises lose competitiveness. TRIZ theory is a complete and systematic innovative design theory, and Su-field is its common problem analysis tool. Combining FEPAM functional solution model with Su-field model, optimizes the standard solution, solves practical engineering problems more efficiently, and achieves the requirements of innovative design. Fig. 1 is the solution flow chart of FEPAM model, Su-field model and standard solution. The steps to solve the engineering problem are as follows:

2.1. Determine product function

The competitiveness of the product depends on the needs of the market and customers. Through the research and analysis of the market, find out the deficiencies of the current product and determine the function of the product. Function is the expression of the working ability of the product, and plays a guiding role in the innovation of the working mechanism scheme. It reflects the task and demand of the design, and can solve the existing defects without weakening the original function.

2.2. Search for product working mechanism

After determining the function of the product, need to find the solution to realize the function of the product, (i.e. working mechanism). The working mechanism can fully and deeply reflect the working process and characteristics of the mechanical structure. Only by understanding the working mechanism can we design products with excellent performance. According to different market demands, different working mechanisms are selected, different product design schemes are solved, and finally realized by mechanical action. The realization process of working mechanism is the realization of product core functions.

2.3. Conceive process action

The implementation of working mechanism and the realization of auxiliary action determine the realization of its core function and auxiliary function. The realization of the function is completed by one action. By summarizing and integrating a series of actions, the process of mechanical structure can be conceived. The commonly used conception method has the anthropomorphic action conception method and the case-based conception method. Anthropomorphic conception method is to conceive the process of action by imitating the actions of people. Instance based conception method is to look for similar examples for reference, such as the conception of the action process of lithography printing machine can refer to the action process of sealing.

2.4. Decompose into several structure

The process of technological action reflects the function and working mechanism of the product, to realize the technological action of the product, it needs to be decomposed into several executable actions, and the decomposed actions should meet the principle of the most simplified, realizable and the least number of actions. The realization of action depends on the structure to ensure that a component can only realize one action.
2.5. Solution of the problem

According to the previous model, find the system that needs to be improved, establish the Su-field model, and adopt different standard solution design ideas according to different needs. When it is necessary to predict the potential of change, the standard solution of the third or second type can be adopted according to the scale of change. When the system needs to be improved, it is judged according to the Su-field interaction. When the interaction is scarcity, the standard solution of type 1.1 shall be applied; when it is harmful, the standard solution of type 1.2 shall be applied; when it is insufficient, the first or second type standard solution shall be applied. The fourth type standard solution is needed when the requirement is detection or measurement. If the problem still cannot be adequately addressed, the problem should be refined again, and a new Su-field model should be established to solve the problem again. If want to continue to optimize the system, we can continue to optimize the system through the fifth type standard solution.

Figure 1. Flow chart of combination of FEPAM model, Su-field model and standard solution
3. Application in engineering

With the continuous development of robotics technology, the demand for service robots is getting higher, especially in the period of fighting against the novel coronavirus. The use of medical distribution robots can assist in the intelligent diagnosis and treatment of epidemic diseases, reduce the risk of infection of medical staff, and provide technical support for the sniping war of epidemic prevention and control. However, most of the existing distribution robots use drawer trunk, which is not suitable for man-machine operation. Therefore, it is necessary to design a distribution robot which is convenient for man-machine operation and reduces the labor intensity. Then, we use the integrated model of FEPAM model and Su-field model to solve the design of the trunk.

3.1. Determine trunk function
The traditional trunk uses a drawer type, which will bring inconvenience to man-machine operation, so it is necessary to improve the traditional trunk. The improved trunk should be able to solve the problem that the traditional drawer type trunk occupies a large space and is not conducive to man-machine operation. At the same time, it should have the function of carrying a certain amount of objects.

3.2. Trunk’s working mechanism
The mechanism has a box, and there are several small boxes in the trunk (used to distribute drugs needed by patients, etc.). During the distribution, the small box should be able to rise to the top of the trunk. When the small box rises, the trunk door should be opened automatically, and the manipulator can grasp it.

3.3. Process action
Using the anthropomorphic motion conception method, the craft motion process can be conceived according to manual operation. From a general perspective, it consists of three actions: opening the trunk door, transporting goods and grasping the goods. The process can be subdivided into:

- When storing goods, the small box in the trunk moves to the highest place and stop moving. The control system will open the trunk door, and then the goods can be placed. When the weight of the box reaches a certain degree, the other box will be sent to the highest place to continue to store goods, and finally complete the storage. When grabbing the goods, if the goods are not in the highest trunk, the trunk starts to move, and the small box is transported until the trunk where the goods are needed reaches the highest point, and the goods are taken.

- It is also possible to use case-based conception method, use the action process of the sweet potato vending machine in daily life as a reference. The storage of goods is similar to putting sweet potatoes into a vending machine, and the taking of goods is similar to taking roasted sweet potatoes. The baking of sweet potatoes is equivalent to the transportation process of the goods, and it also helps in the conception of craft actions.

3.4. Structure decomposition
According to the process action, it can be divided into three structure, as shown in Figure 2.

![Function distribution diagram of trunk structure](image-url)
3.5. Problem solving

In order to realize the smooth transportation of goods, the system is improved and designed. First of all, the trolley box placed in the rack can’t achieve the function of upward transportation. The established Su-field model is the first kind of Su-field model, Incomplete functions. The standard solution adopted is 1.1 type standard solution, which improves the system with incomplete functions.

For only S1 trolley box, S2 chain mechanism and F mechanical field are added. The trolley box can be transported by sprocket mechanism. As shown in Figure 3(a), the whole system is installed on the box rack. The base is fixed at the left and right ends of the box rack, and the sprocket is fixed on the base. The sprocket is connected through the shaft to achieve the transmission effect. There are several trolley boxes on both sides of the sprocket. When the motor drives the sprocket to rotate, the left and right chains move synchronously to drive the carriage to rotate and complete the function of goods transportation.

After applying the class 1.1 standard solution, according to the flow chart, the third type standard solution is used, don’t need to convert the system into dual system, multi system or micro level. When answering the question whether the solution is sufficient, it is found that there will be harmful effects in the transmission process of the trolley box, and the transmission process is unstable, so it is necessary to improve the system. The established Su-field model is the fourth kind of Su-filed model, Harmful functions. 1.2 type standard solution is used to eliminate or offset harmful effects, balance mechanism is added, which includes vertical linear balance mechanism and arc balance mechanism to eliminate harmful effects. The vertical linear balance mechanism is realized by sliding block and guide rail. The guide rail is installed on the box rack vertically. The sliding block is installed on both ends of the connecting rod on the trolley box and takes the limiting effect. The bayonet on the other side of the sliding block blocks the guide rail. The clearance between the two makes the trolley box move along the vertical direction. Due to the sprocket drive, the vertical linear balance mechanism can not achieve stable transmission when the arc movement, so the balance device of the arc part is needed.

Figure 3. Scheme 1: (a) vertical circulation structure (b) circular balance structure (c) circulation distribution truck structure

The addition of slide rail and planetary gear train can solve the problem of smooth transportation to a large extent, but it still can’t be fully solved, because it can’t ensure that the slide will fall on the slide rail after the circular transportation, which may lead to friction and impact of these harmful...
functions. The third type standard solution, standard solution 3.1, can be used to transform the original two sprocket system into three sprocket system. As shown in Figure 4, the trolley box is also driven by chain wheel. Chain wheel 1 and chain wheel 2 are parallel and eccentric, and the other end is connected with chain wheel 3. Connecting rod 1 and 2 are respectively fixed on chain wheel 1 and 2. When the chain wheel rotates, connecting rod 1 and 2 are fixed to form a parallel connecting rod mechanism, so as to ensure the parallel of rod 2, so as to ensure the stable movement of the trolley case, and at the same time It also solves the problem of the above scheme.

![Diagram](image_url)

Figure 4. Scheme 2: Structure of three chain wheel trunk

4. Conclusion
In this paper, the Su-field model in TRIZ theory is combined with FEPAM model in traditional mechanism design. Starting from the requirements and the defects of existing products, the core functions to be realized are found. Then the mechanism to be improved is found according to FEPAM model. The function design is realized through the establishment of Su-field model and the application of standard solution, and the product innovation is completed. The organic combination of the two models not only improves the efficiency of the Su-field model, but also enriches the model of standard solution. Finally, the feasibility and applicability of the method are verified by an example, which provides a new idea for the follow-up study of Su-field.

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