# Requirement identification and disassembly of electromechanical products based on domain knowledge network

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## ABSTRACT

The core of requirement analysis is to fully and accurately obtain customer requirements from requirement data. Nowadays, with the development of computer technology and e-commerce, a large number of personalized electromechanical products requirement data appear on various network platforms. The traditional requirement analysis methods are difficult to deal with it. This paper proposed a method of requirement identification and disassembly of electromechanical products based on domain knowledge network. The existing electromechanical domain knowledge is reused to identify and disassemble the requirement text expressed by the customer in the unstructured form of natural language. Based on this method, this paper developed a computer-aided requirement analysis tool, which can assist designers to quickly clarify the requirement.

**Keywords:** Requirement analysis, knowledge network, conceptual design, product design

## 1. INTRODUCTION

With the increasingly fierce market competition of electromechanical products, requirement has increasingly become the premise and guidance of innovative design of electromechanical products[1]. The traditional methods of requirement mining and analysis include analytic hierarchy process[2, 3], questionnaire analysis based on Kano model[4, 5], etc. The traditional requirement analysis method can help designers analyze customer requirement more accurately. However, this method usually depends on manual consultation, questionnaire survey and other activities. The research cost is high, and it is easy to produce information deviation and insufficient reliability. It is difficult to apply to the massive outbreak of requirement data.

With the advent of the data age, many data-driven requirement analysis methods have been proposed, such as consumer requirement data quality evaluation, customer emotion polarity and its corresponding opinion target analysis, and automatic ranking of customer requirement importance[6]. Yao Y proposes a three-stage method to identify product feature names from customer opinion data. In the first stage, the brown clustering algorithm is applied to obtain word clusters with similar meanings, and the changes of brand names are captured by language rules. In the second stage, the method based on conditional random fields (CRFs) is used to analyze whether a word really refers to a specific product model name. In the third stage, rule-based name normalization is used to map names to their formal names[7, 8]. Zhou F uses fast-text technology to obtain comments containing useful information from Internet product reviews, extracts various topics related to customer needs through a topic modeling technology, and finally predicts the emotion category and intensity of consumers in comments through rule-based emotion analysis[9]. Polpinij J uses support vector machine and other technologies to classify customer demand text data, extract the characteristics of customer demand text data, and then analyze the emotional polarity[10].

With the development of e-commerce, the amount of personalized requirement data in the form of customer comments on internet platforms has exploded. Because the customers are generally not professionals, the expressed requirement has the characteristics of fuzziness and incompleteness. On the one hand, the storage cost and processing cost of massive low-quality data are high, and the acquisition cost of massive high-quality data are high; On the other hand, there are many missing values in the requirement data, and it is difficult to accurately quantify the data, categories and attributes. Therefore, knowledge aided methods and tools are needed to assist designers and customers to quickly clarify

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requirements.

The method of knowledge aided requirement analysis can reduce the burden of designers dealing with massive personalized customer requirement data, so that designers can focus more on the links of innovative design. At present, knowledge aided requirement analysis methods include knowledge retrieval based on keyword and file name matching[11], rule-based reasoning[12] and case-based reasoning[13]. The method based on keyword and file name matching is simple and easy to implement, but the knowledge granularity is large, which is difficult to be directly used by designers. The method of rule-based reasoning has simple knowledge representation and strong reasoning ability. However, with the expansion of knowledge scale, its reasoning efficiency will decline sharply. The case-based reasoning method can solve new problems by using the past requirement analysis cases, and solve new problems by retrieving the most similar cases. However, the interpretability of knowledge acquisition in this method is weak.

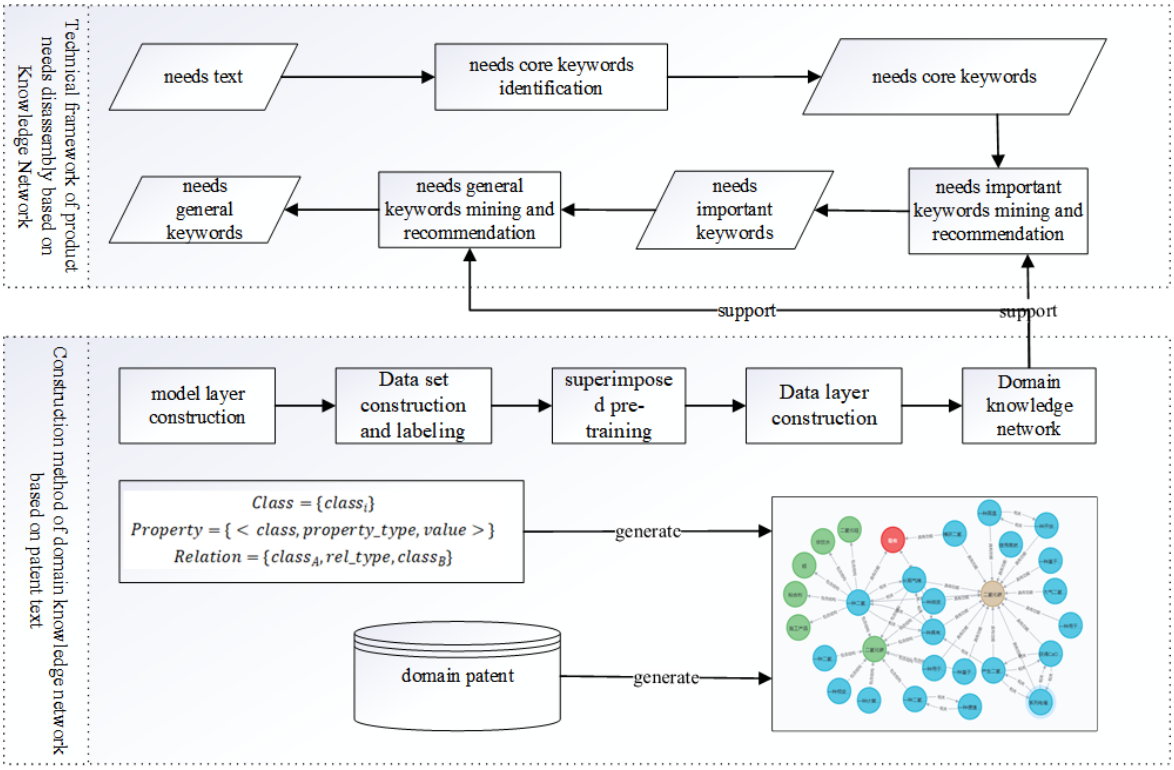


Figure 1. Framework diagram of electromechanical products requirement identification and disassembly technology based on domain knowledge network.

We propose a method of electromechanical product requirement identification and disassembly based on domain knowledge network. This method can identify and disassemble the requirement text expressed in the unstructured form of natural language, and obtain the keywords that can accurately and fully represent the meaning of customer requirement. The framework of this method is shown in Figure 1. Firstly, we construct a domain knowledge network based on ontology, and then reuse knowledge in the process of customers requirement analysis. Because ontology has the characteristics of standardized expression and accurate description of the relationship between entities, this method can describe knowledge at the level of entity granularity, and has advantages in knowledge reasoning. Finally, based on this method, we develop a requirement identification and disassembly tool for electromechanical products to assist designers and customer to quickly clarify requirement.

## 2. CONSTRUCTION METHOD OF DOMAIN KNOWLEDGE NETWORK BASED ON PATENT

In order to support the requirement identification and disassembly method of electromechanical products based on

domain knowledge network, we propose an automatic construction method of domain knowledge network based on patent. Because the requirement description of electromechanical products has the characteristics of semi professionalism and concealment. We divide the requirement elements into functional elements and structural elements based on axiomatic design theory, and expresses the functional elements into function-operation and function-object based on behavior theory. The process of this method is shown in Figure 1.

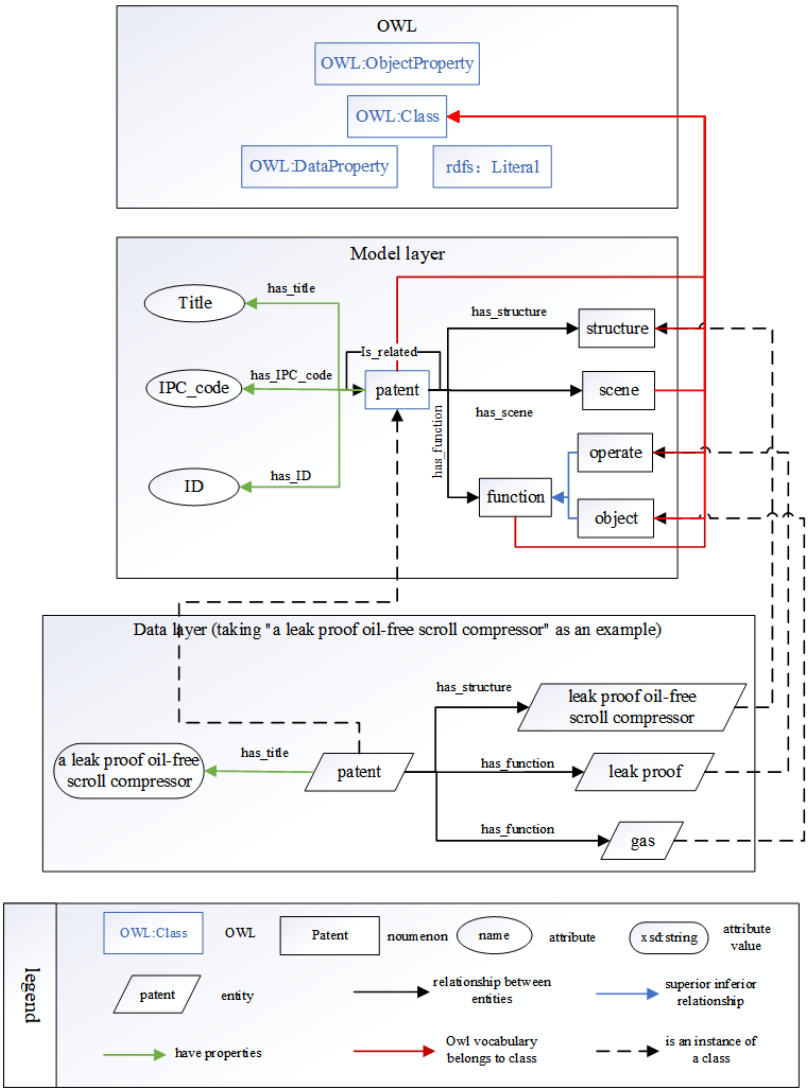


Figure 2. Model layer of domain knowledge network.

(1) Model layer construction. We represent the pattern layer of knowledge network as triples $< Class, Property, Relation >$based on network ontology language (OWL), as shown in figure 2:

$$\begin{aligned} \boldsymbol{Class} &= \{\boldsymbol{class_i}\} \\ \boldsymbol{Property} &= \{< \boldsymbol{class}, \boldsymbol{property\_type}, \boldsymbol{value} >\} \\ \boldsymbol{Relation} &= \{\boldsymbol{class_A}, \boldsymbol{rel\_type}, \boldsymbol{class_B}\} \end{aligned} \tag{1}$$

where $Class = \{class_i\}$ specifies the node class and the upper and lower relationship between classes in the knowledge network; $Property = \{< class, property\_type, value >\}$ stipulates that the attributes and property values of various entities in the knowledge network; $Relation = \{class_A, rel\_type, class_B\}$ stipulates the relationship between various

entities.

(2) Data set construction and labeling. We obtain relevant patent data, analyze the patent, and BIO mark the parsed title and abstract text.

(3) Superimposed pre-training of the model. We complete the superposition pre-training of the model based on the patent data to improve the recognition ability of the mode.

(4) Data layer construction of domain knowledge network. It mainly includes the construction of patent entity and the extraction of attribute information; Function-operation entity, function-object entity, structure entity and scene entity extraction model construction; Relationship generation in domain knowledge network. We use Bert model to extract Function-operation entity, function-object entity, structure entity and scene entity. According to the definition of knowledge network mode layer, the relationships in knowledge network can be divided into four categories: “has_function”, “has_structure”, “has_scene” and “is_related”. The structural similarity between patent entities is based on the Jaccard similarity. It is considered that the structural similarity between patent entities with more identical functions and structural entities is higher.

## 3. REQUIREMENT IDENTIFICATION AND DISASSEMBLY METHOD OF ELECTROMECHANICAL PRODUCTS BASED ON DOMAIN KNOWLEDGE NETWORK

Now we can realize the requirement identification and disassembly method of electromechanical products based on the domain knowledge network. We divided these keywords into Core Requirement Keyword (CRK), Important Requirement Keyword (IRK) and General Requirement Keyword (GRK). The CRK is the explicit requirement for product functions, structures and scene clearly expressed by customer in the requirement text. The IRK are the standardized expression of the CRK based on the domain knowledge network, which is the result of matching the CRK with the relevant entities in the domain knowledge network. GRK are the results of mining implicit requirement that are not clearly expressed by customer based on IRK and domain knowledge network. They can accurately and fully express the meaning of the customer requirement. As shown in Figure 1, the specific process of this method is:

(1) Customer input requirement text;

(2) The CRK identification model identifies the CRK in the customer requirement text, and obtains the final CRK after customer interaction. Based on natural language processing technology, this paper classifies and extracts the CRK in the customer requirement text;

(3) Based on the constructed domain knowledge network, the similarity matching of the CRK is carried out to obtain the IRK, and then the final IRK are obtained after the customer interaction. In the domain knowledge network, we match the CRK and knowledge entities based on semantic cosine similarity calculation;

(4) Based on the domain knowledge network and IRK, the customer requirement is mined and supplemented to obtain the GRK. Similarly, after the customer interaction, the final GRK are obtained. Based on the network structure similarity calculation and link prediction technology, we recommend possibly related knowledge entities to designers and customer, and obtain the GRK.

## 4. APPLICATION DEVELOPMENT

Based on the requirement identification and disassembly technology of electromechanical products based on domain knowledge network, we develop the requirement identification and disassembly tool of electromechanical products based on domain knowledge network. The framework of the tool is shown in Figure 3.

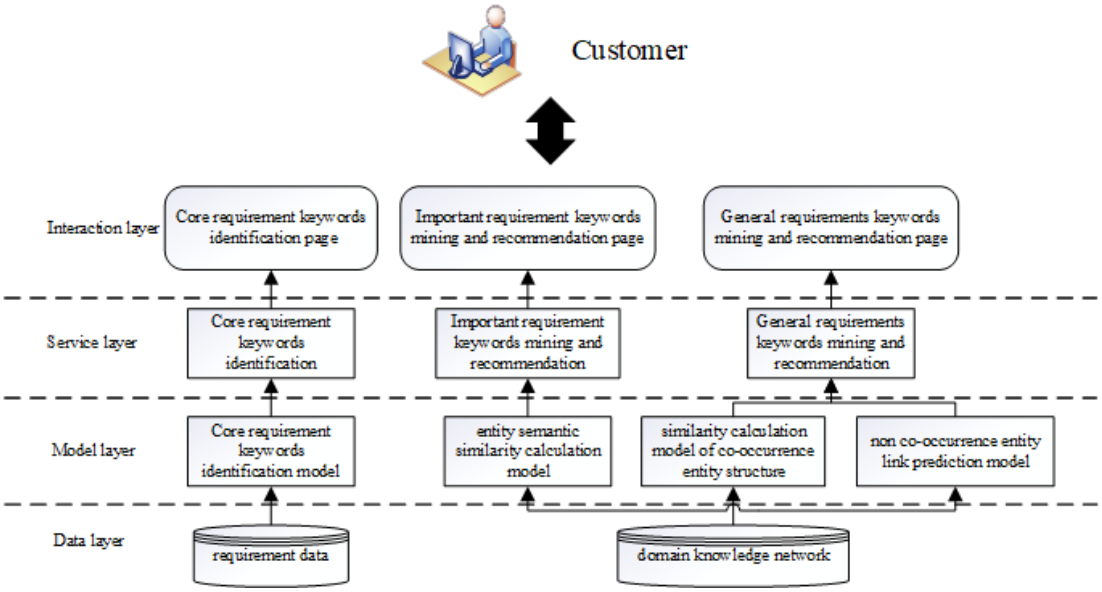


Figure 3. Tool system structure.

## 5. APPLICATION EXAMPLE

Taking a real electromechanical product requirement description text as an example, we introduce the process of electromechanical products requirement identification and disassembly tool based on domain knowledge network, so as to verify the feasibility of the requirement identification and disassembly method based on domain knowledge network. The process and results are as follows:

(1) The customer enters the requirement text and clicks the "requirement element analysis" button. The requirement text is:

"The inner steamer has a pressure relief port at the top of the inner tank. We hope to install a pressure relief valve at the pressure relief port, which can control the pressure in the steamer and realize rapid cooking. At present, the wax motor is installed at the pressure relief port, which can only keep the pressure relief port closed at low temperature, and will automatically open when the temperature is high, which can not maintain the pressure in the steamer. At present, we need to find a mechanical pressure relief valve (safety valve) Resources or solutions to solve the problem";

(2) The CRK returned is: function-operation elements "pressure relief" and "cooking"; Function-object element "pressure" and "steamer"; Structural elements "pressure relief valve", "steam box" and "pressure relief port"; After selection by the customer, the CRK of the final demand is function-operation element "pressure relief" and structural element "pressure relief valve";

(3) Based on the semantic similarity calculation and customer selection, the CRK and knowledge entities are matched to obtain the IRK, as shown in Table 1;

(4) Based on the similarity calculation of knowledge network structure and link prediction, tool returns the GRK, as shown in Tables 2 and 3;

(5) The tool has been tested in a well-known household appliance enterprise in China. In the process of using the tool for requirement identification and disassembly, the accuracy of mining and recommendation of requirement keywords in the three functional modules of the tool is high, and the method shows good effectiveness and reliability when assisting designers to complete the task of requirement analysis. It can be seen from the above cases that the keywords identified CRK identification module of the tool basically includes the requirement elements; The IRK recommended by the mining and recommendation module are semantically similar to the CRK.

Table 1. Mining and recommendation results of IRK.

| Semantic related entity (pressure relief) | Cosine similarity | Semantic related entity (pressure relief valve) | Cosine similarity |
|---|---|---|---|
| Pressure relief | 100% | Pressure relief valve | 100% |
| Carrying pressure | 98.54% | Pressure relief valve core | 99.6% |
| Under pressure | 98.5% | Pressure relief valve group | 99.46% |
| Diffuser | 98.44% | Pressure relief valve plate | 99.46% |
| Pressure boost | 98.34% | Pressure relief valve head | 99.46% |

Table 2. GRK mining and recommendation results of “pressure relief valve”.

| Structure related entities | Jaccard similarity | Link prediction related entities | Cosine similarity |
|---|---|---|---|
| **Pressure relief pipe** | 3.47% | Metal block | 91.12% |
| **Air storage tank** | 3.41% | Thread blind hole | 89.70% |
| **Pressure relief hole** | 3.24% | Vacuum cleaner | 89.70% |
| Auxiliary pulley | 2.89% | Semicircular groove | 88.94% |
| **Pressure relief port** | 2.89% | Elastic element | 88.17% |

Table 3. GRK mining and recommendation results of “pressure relief”.

| Structure related entities | Jaccard similarity | Link prediction related entities | Cosine similarity |
|---|---|---|---|
| Set-down | 3.57% | **Encapsulation** | 65.97% |
| Ventilate | 3.44% | Poisoning | 60.75% |
| **Pressure maintaining** | 2.63% | Line selection | 60.69% |
| Anti stripping | 2.50% | Production | 60.18% |
| Explosion-proof | 2.19% | Rust prevention | 60.06% |

## 6. CONCLUSIONS AND PROSPECTS

This research mainly focuses on the problem of requirement analysis in the field of electromechanical products, and puts forward the method of requirement identification and disassembly of electromechanical products based on domain knowledge network. There are three main contributions: (1) We propose a patent based automatic construction method of electromechanical domain knowledge network, which can automatically complete the process of obtaining relevant entities and relationships from patents, and finally build a domain knowledge network that can support the requirement identification and disassembly methods of electromechanical products; (2) We propose a method of requirement identification and disassembly of electromechanical products based on domain knowledge network, which can obtain keywords that can accurately and fully reflect the customer requirement, and help designers effectively mine and analyze the customer requirement. (3) We develop a requirement identification and disassembly tool for electromechanical products based on domain knowledge network.

The research still has deficiencies in some aspects, which needs to be expanded and deepened in the follow-up research. (1) We do not fully analyze the characteristics of the scene in the customer requirement text and fails to clearly define the scope and category of the scene. In the process of customer requirement identification and disassembly, the scene

elements contained in the requirement are not well utilized. (2) The knowledge network in the method of identification and disassembly of mechanical and electrical products based on knowledge network is lack of scalability. In practical engineering application, knowledge has not only static independent knowledge fragments, but also dynamic continuous knowledge. Knowledge has an evolution process, and practical engineering will continue to need new knowledge. Therefore, the knowledge network in practical engineering application should be expandable in order to incorporate new knowledge in time.

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