

# Research on Product Conceptual Design Methods and Ontology Construction Based on Knowledge Graphs

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**Abstract:** Product concept design is a complex process, the existing design methods in a short period of time to provide designers with very limited design ideas, with the aid of emerging technologies for product design will greatly improve the design efficiency, through the construction of knowledge graph will help designers in a short period of time to find the design ideas to improve the design efficiency. Through the study of knowledge graph, the knowledge graph construction process in the field of product design has been established. This paper takes automobile as an example, conducts data collection of design knowledge, and obtains a preliminary corpus of design knowledge through data processing. After data analysis, five major categories are identified for ontology construction. Based on the ontology knowledge, the ontology layer of automobile appearance design is constructed by utilizing the seven-step method, so as to do the prospective work for the knowledge graph construction in the design field.

**Keywords:** Knowledge Graph; Product Design; Design Methodology; Data Mining; Ontology Layer

## 1. Introduction

Product concept design is a ponderous process of design knowledge fusion<sup>[1]</sup>, and in the current stage of the product concept design process, designers' acquisition of design knowledge needs to be carried out by constantly rummaging through design inspiration websites and historical product databases, so as to fuse old and new design knowledge. Designers' search for design knowledge is a long and inefficient process, and in today's design environment with short

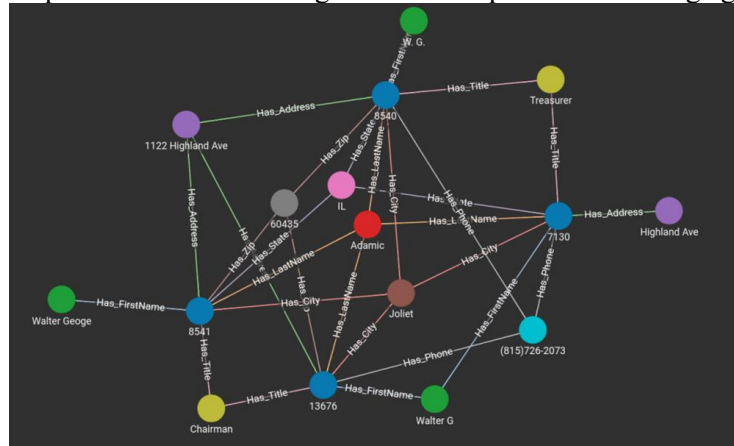
product life cycles, the speed of acquiring and integrating design knowledge determines the extent to which a product occupies a share of the market<sup>[2]</sup>. As designers, they also work alone for a longer period of time, which requires us to use modern and already mature technologies to solve for designers the toughest problem in product design: that is, how to quickly create breakthrough or highly innovative products. Product conceptualization methods based on knowledge mapping can help solve this problem. The knowledge-driven design field realizes the reproduction of knowledge in the form of knowledge graph, and integrates and organizes the fragmented, poorly reasoned, and poorly visualized design knowledge. Knowledge graph has significant advantages in automation, reasoning, and visualization, which can effectively improve the efficiency of knowledge acquisition and enhance the efficiency of design.

## 2. Status of Knowledge Graph Research

The initial origin of knowledge graph can be traced back to the period of Turing test, the idea of how to make computers understand human language and knowledge to think and solve real problems like humans was put forward, and the research of knowledge representation methods was emphasized<sup>[3]</sup>. Knowledge graphs or knowledge bases are mostly constructed manually by experts. 2012 Google Inc. formally proposed the concept of knowledge graphs and embodied a huge development potential after applying it to search engines, which set off a craze in the academic and corporate worlds, and numerous excellent academic and application results emerged<sup>[4]</sup>. Amazon, Facebook and other international Internet companies<sup>[5]</sup> have announced the progress of research in the knowledge graph and applications, in 2013, Baidu released "know the heart", the same

year Sogou “know the cube”, Microsoft “Satori” also released. Microsoft “Satori” was also released one after another. In the academic world, automated knowledge acquisition and construction of knowledge graph research also presents a blossoming

trend, such as foreign DBpedia<sup>[6]</sup>, YAGO<sup>[7]</sup> and WikiData and other large-scale knowledge graphs, and the emergence of Zhishi.me, CN-DBpedia and other high-profile Chinese knowledge graphs in China. Figure 1 shows an example of a knowledge graph.

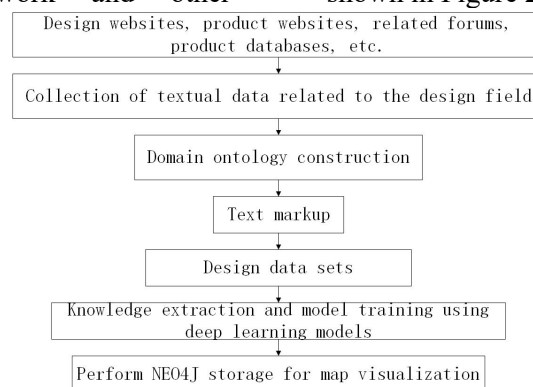


**Figure 1. Example of a Knowledge Map (Figure from the Internet)**

After the development of computer technology and the progress of information visualization, knowledge graph technology also extends the development of knowledge graphs to different industries of vertical industry domains, in which the development of artificial intelligence, biomedicine and finance and other fields is the most significant. In the field of biomedicine more typical foreign Linked Life Data, UMLS, Diseasesome, the domestic typical Chinese medicine knowledge graph and Chinese medicine semantic network and other

large-scale knowledge graph [8]. Although the knowledge graph construction work in the field of product design is progressing more slowly, more researches are emerging.

Product concept design based on knowledge mapping is an innovative auxiliary design method, which utilizes the relevance and structured data of knowledge mapping to provide comprehensive information support and intelligent analysis for product design. The specific process of mapping construction is shown in Figure 2 below.



### Figure 2. Knowledge Graph Construction Process

### 3. Product Concept Design Knowledge Mining and Data Processing

The construction of product conceptual design knowledge graph first needs the support of corpus data, through the mining of corpus data, the construction of knowledge graph corpus knowledge base is realized. A large amount of corpus data is collected by means of web

crawler to construct the preliminary corpus required for the mapping, which paves the way for the subsequent steps. Web crawler is a kind of script that automatically and quickly crawls network information based on specific rules. Currently, crawler technology is widely used in fields such as web intelligent search. In addition, based on the current user's operating behavior, through the web crawler technology,

when obtaining information about the user's subsequent operations, the system sends a request message to the server, so that the user can obtain the requested web page information. Web crawler technology greatly improves the efficiency of data acquisition, thus more convenient to meet the needs of users.

Octopus and Python are two more commonly used data crawling tools. Octopus operation is relatively simple, but the crawling efficiency is not high, is not suitable for huge data crawling, Python software can be very fast crawling huge data, greatly reducing the time of data crawling, improve the system's service efficiency, and improve the accuracy of the crawling results.<sup>[9]</sup>

In this paper, we select "Audi", a brand with important status and influence in China's

automobile industry, as the object of knowledge graph construction, and select Audi Q5L as the initial experimental object. The case is based on the real user review data from "Auto Home" and "Aika Auto" to build a preliminary product concept design corpus in the automotive field by brand and dimension, and to analyze the users' real evaluation of automotive products. The two dimensions of "appearance" and "interior" are targeted to crawl the relevant user review data. The Octopus collector and Python crawler were used to crawl 16884 user comments in the word-of-mouth interface of "Auto Home" and "Aika Auto". Among them, there are 9,364 comments on "exterior" and 7,520 comments on "interior", some of which are shown in Figure 3.

Configuration is really a bit unfair. However, I have consulted and it seems that everything except for cruise control can be upgraded, but do not upgrade at the 4S store. Upgrading genuine leather seats at the 4S store is 9000 monochrome and 12000 dual color. Navigation 19000. Damn it, I was sweating when I heard it. If I went out and found someone to upgrade myself, it would be 3500 pairs of genuine leather. Navigation, with reversing camera, probably less than 5000. Actually, the 4S dealership also hired these people to upgrade, but they have to support their employees, and the extra money will be paid off, haha. The price range is a bit wider, the configuration is not very high, the higher-level technical models are more than 50000 yuan more expensive, and now you have to pay extra to buy them. I don't know when I will receive the car, and the problem of burning oil seems to have not been solved yet. A car worth over 400000 yuan doesn't even have GPS. This is also too unreliable!!!

1. The configuration is too low, even the devices that are equipped in domestic cars priced at 100000 yuan are not equipped - not even GPS navigation and anti glare rearview mirrors, reverse image, and multifunctional steering wheel. 2. The rear distance is small and the space is low. Sitting in the back row, I can't stand up straight with my head covered. The distance between the legs is small and cannot be moved. 3. According to common feedback, the problem of burning engine oil is very serious. What's going on? 4. Maintenance is too expensive, just changing the oil (including the oil filter) costs over a thousand yuan. Other maintenance and replacement parts are more expensive. 5. The majority of gasoline used in China is 93 octane, while this car uses 97 octane gasoline. As an SUV model, it is inevitable to go to the countryside. What if there is no 97 octane gasoline at a small town gas station, only 93 octane gasoline? The cost of oil is also much higher.

There are too many drawbacks to this! Firstly, for the aggressive model, there are no genuine leather seats, eh. Audi brother, nearly 400000 yuan, surprisingly, the price of a mid-range specification car does not include mid-range specifications. Again, the aggressive model doesn't have an electric rearview mirror, wow! Driving a 40W car wouldn't be too fancy, would it! Although the entire 2011 series uses xenon lamps, although there are cars in the warehouse, they have to be sold at a markup. I seriously despise you. Audi!

Audi only has a market in China to fool Chinese people. It's always the same old style for 100 years. It's disgusting to look at the first circle - ugly appearance, the second circle - interior soil, the third circle - low configuration, the fourth circle - rough workmanship and many defects. Please input 'complain about Audi' and 'Audi accident' respectively in Baidu. You will see how rubbish Audi is. Wu Yousheng, Director of the Information Management Department of the Defective Product Management Center of the General Administration of Quality Supervision, Inspection and Quarantine, once revealed to the media that Audi ranked first in China in terms of complaint rate according to the number of complaints. In the recent routine complaint report of the Automotive Professional Office of the Shanghai Consumer Rights Protection Committee, the Audi brand has received far more complaints this year than in previous years and has been criticized by name. The common complaints are oil burning and brake failure. Spontaneous combustion, water pump leakage, inability to deploy safety airbags, transmission issues, high engine noise, premature aging, and shaking of the entire vehicle have repeatedly occurred in places such as Daqing, Handan, and Shanghai in Heilongjiang Province.

The price range is a bit too wide, and the configuration is not very high. A car priced at over 400000 yuan doesn't even have GPS. Maybe it's just that the brand is harder

The oil problem of the 2011 model has not been resolved yet. After 3000 kilometers, the oil dipstick on the driving computer shows that one-fifth is left. The other eight speed automatic transmission has a noticeable jerking sensation when shifting between first and second gears (I don't know if this is the case with dual clutch transmission), while other gears are very smooth. After getting used to it for a while, I feel much better. The trunk of the car is a bit small (except when the rear seats are folded down). The navigation operation of MMI is not as user-friendly as that of handwriting screen.

Very good, very good, both the appearance and power are comfortable. In fact, you can buy an aggressive model and upgrade it yourself, which costs less than 30000 yuan and basically has everything. This only costs 40000 yuan. After all, you are buying a car, and the main focus is on the engine and gearbox. The configuration can be upgraded by yourself.

A domestically produced car with a starting price of 270000 yuan should have relatively high configuration, but it lacks basic features such as keyless start and electronic navigation. Compared to imported cars, there is a significant difference in appearance. The exhaust pipes and grille are not good, and the rear space is relatively small; Raising the price for car pickup is even more annoying and self-destructs the brand image. Originally, Audi was the first choice for changing cars, but the marketing behavior was chilling, so I decided to switch to BMW. In the same class, BMW's configuration is much stronger than Q5, while Audi is too arrogant, and its market share will eventually be surpassed by other brands.

The appearance looks mediocre and low-key. Ordinary mind. The engine is good, and so is the gearbox.

**Figure 3. Preliminary Information on the Corpus**

When users express their subjective feelings, a large number of meaningless words will be mixed in, such as "it seems to me", "it is obvious" and some other pause words and intonation words, which do not contribute much to the post-textual analysis, and need to be screened and removed. Since the focus of this study is on the content of the description of the exterior design of the Audi Q5L, words that have significance in the automotive field may still be meaningless in this study, such as "fight", "upright", "Stability", 'cost-effective',

'handling', and 'automatic transmission' are words that cannot express the connotation of the external form of the automobile product. Therefore, they need to be eliminated in preprocessing. Text preprocessing can reduce the redundancy of text features and the noise of the dataset, thus further improving the accuracy of text mining. After data processing, 8645 comments on "exterior" and 6552 comments on "interior" are obtained, and the preprocessed text data is shown in Figure 4.

The appearance of Q5L is the most common dynamic type

The Q5L's exterior design is quite impressive, with a black paint that gives a sense of stability and grandeur, a unique sense of grandeur, and a touch of sporty genes. The front grille has a stylish and sporty design

The front and rear of the Q5L are quite in line with my personal aesthetic, and the waistline is also simple and elegant

The Q5L vehicle is black in color, giving an overall impression of being very stylish and sturdy. The lines of the car are also quite distinct, with a streamlined design at the rear, which is relatively young and fashionable.

Q5L, 24 models, luxury sport comes with a black light bag and red calipers, combined with the overall black color, this small sporty atmosphere comes out immediately.

The exterior design of the vehicle is elegant and full of tension. The front of the car adopts a unique design language, paired with sharp LED headlights and exquisite air intake grille, making the entire front of the car look both fashionable and powerful. From the side body contour is elegant and layered, with simple yet stylish wheel hub design that perfectly matches the body color, creating a coordinated and unified visual effect. The rear part of the car is equally stunning, with four exhausts that give it a sporty feel and also give it a rebellious personality. The unique design of the taillights adds a touch of futurism and technology to the entire vehicle.

The exterior design showcases the fusion of youth and vitality. The body contour is smooth and full of power. At the front of the car, the intake grille cleverly incorporates the brand's iconic elements, and the deep black tone adds a sense of mystery. The headlights are like the brightest stars in the night sky, not only powerful in function, but also the visual focus. The body lines are elegant and layered. The wheel hub design is simple yet not simple, perfectly matched with the body color. The rear design is equally stunning, with four exhaust pipes not only showcasing the vehicle's strong power, but also giving it a rebellious personality. The unique shape of the taillights adds a touch of futurism to the entire vehicle.

The design of the appearance is very recognizable. The body lines are smooth and dynamic, and the overall design is stylish, atmospheric, and stable. The tail design is also very unique and full of three-dimensional sense!

The appearance is very sporty and cool. I am quite satisfied with the overall appearance of Audi, with a strong sense of technology

The exterior design is dynamic, and the overall body lines and waistline curve design are more sporty.

The appearance is also what attracts me. The design is very youthful, with a smoked black front grille and the entire car logo, red calipers, giving a sporty feel

On the outside, the lines are beautiful and the front face is grand, only lacking a matrix headlight. Rear styling: 45 degree perspective, streamlined feeling comes out

**Figure 4. Corpus after Data Cleaning**

#### 4. Product Concept Design Domain Ontology Construction

Through the preliminary corpus cleaning data already has a certain structure, through the analysis of these corpus to construct a domain ontology, constructed ontology framework helps to predefine the entities in the process of knowledge graph construction, for the next step in the knowledge extraction to make a good foundation.

##### 4.1 Concept and Connotation of Ontology

The concept of ontology was first introduced in the field of philosophy, and its initial meaning was “a systematic description of the world's objects are objective”, which conceptualizes the essence of objective things. With the continuous development of social science and culture, artificial intelligence, computer and Internet technology is also developing, the concept of ontology began to receive attention in more fields. Ontology knowledge base refers to the use of ontology technology to build a knowledge base system based on ontology theory<sup>[10]</sup>.

After the introduction of various domains, ontology is used to model the concepts within a specific domain, as well as the formal description of the relationship between the concepts. Domain ontology is a specialized ontology for each domain, which is mainly used to formally describe the concepts in a specific domain and the relationships between the concepts. By constructing an ontology, it is possible to organize the concepts and relationships within a domain. By supplementing the corresponding attributes and axioms to construct the knowledge expression model in the domain, the reuse and sharing of knowledge can be realized, and some researchers and scholars define the ontology as a five-tuple model.

$$\text{Onto} = \langle C, I, A, R, X \rangle \quad (1)$$

where C denotes the domain to which the domain ontology belongs, I denotes the concepts of the domain ontology, A denotes the attributes of the domain concepts, and R denotes the concepts between the concepts. attributes of the domain concepts, R denotes the semantic relations among the concepts, and X denotes the concrete instances of the concepts. At the semantic level, the relations in the ontology correspond to different object

tuples. In this study, the domain knowledge concepts involved in product design are characterized by using the form of ontology, which is a conceptual definition of product design knowledge in terms of ontology tuples, and its model formula is:

PFADKO={PFADKCon, PFADKAtt, PFADKRel}(2)  
PFADKo (Product Family Appearance Design Knowledge ontology): product design knowledge ontology;  
PFADKc (Product Family Appearance Design Knowledge Concept): a collection of entities, containing appearance design element entities;  
PFADKa (Product Family Appearance Design Knowledge Attribute): a collection of instances of design knowledge element entities;  
PFADKr (Product Family Appearance Design Knowledge Relationship): a collection of associative relationships between design knowledge concepts, which in the study specifically refers to the hierarchical relationships of instances in design elements.

##### 4.2 Ontology Construction Methods

So far, ontology technology has not formed a unified method system to build a knowledge base system, and the methods of building also have the characteristics of their respective fields, the reason is that most of the methods are summarized by scholars from their own construction of the ontology project, among which the seven-step method, the TOVE method, the skeleton method, the KACTUS engineering method, etc. are more common. In this paper, we will use the seven-step method to build an ontology for the product design domain, and the construction process is shown in Figure 5.

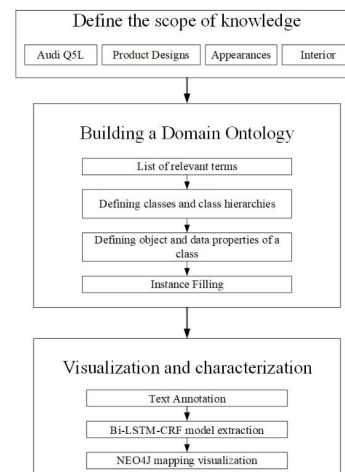


Figure 5. Ontology Construction Flow



Ontology is a condensed and professional clear description of the connotation of the entity, which can explain and elaborate the relationships and concepts of the entity layer under the ontology layer, and the ontology for a specific domain can be understood as a concept or a class. In this paper, we mainly take the Audi Q5L automotive document corpus as the main data source, and realize the construction of ontology layer through layer-by-layer extraction.

Due to the uniqueness and complexity of the intrinsic knowledge structure of automotive product design, the construction of its knowledge ontology is carried out in the form of a seven-step top-down approach, defining classes, attributes and instances of key concepts according to each step.

Step 1: Determine the domain and scope of ontology construction

The study starts from product design, taking Audi Q5L as an example, and determines the ontology of Audi automobile domain by studying the text corpus of its involved appearance design aspects, combining with Audi's own corporate culture as well as design concepts, as an illustration of the ontology.

Step 2: Extract the conceptual terminology of Ma Audi's product field

In this paper, by extracting the knowledge information related to Audi exterior design and extracting the key knowledge concepts through data analysis, it can be seen that the knowledge of Audi exterior design can be divided into 5 main aspects: "shape", "material", "Color", 'Interior' and 'Style'.

Step 3: Define the concepts and their hierarchical structure

By organizing and analyzing the key knowledge concepts extracted in the second

step, the Audi exterior design knowledge is classified, and a top-down approach is adopted to construct the categories of the Audi exterior design knowledge ontology. Construct the large class, i.e., the first-level class, and then gradually refine it to show the hierarchical relationship of the class in the form of a tree diagram.

Step 4: Define conceptual attributes

By organizing and defining the conceptual attributes of Audi exterior design knowledge, the concepts interact with each other to create some kind of connection.

Step 5: Evaluate and test the semantic hierarchical relationship of Audi automobile design knowledge.

In the ontology model of Audi automobile design knowledge, the correlation between instances and the constraint relationship need to be considered, which is expressed as (Entity, Attribute, Attribute Value) in a ternary group, and the relationship between the ontologies can be expressed as (Entity, Relationship, Entity) in a ternary group, and sometimes it is necessary to constrain the attributes.

Step 6: Instantiate the ontology

Through the analysis in the design elements, organize and add as instances to the corresponding classes of the constructed Audi ontology, then establish constraints on the design elements and knowledge within the elements according to the conceptual attributes, and use the constraints to make the corresponding connection between the instances.

Step 7: Visualize the ontology

By populating the above ontology instances and mining the conceptual hierarchy, the above ontology hierarchical relationships are visualized as shown in Figure 6.

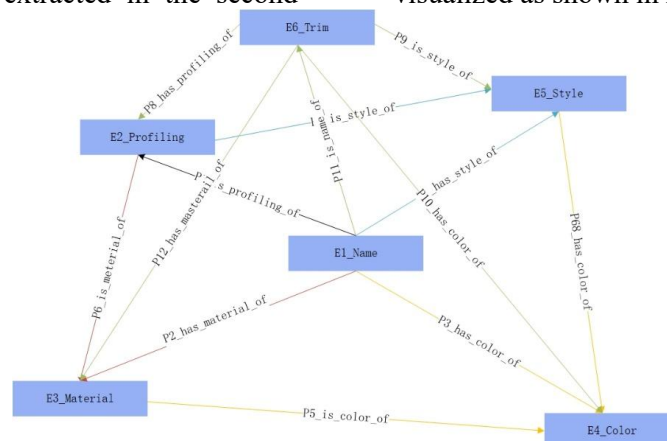


Figure 6. Domain Ontology Construction

## 5. Summary and Prospect

This paper takes Audi Q5L model as an example, carries out data mining and data cleaning, and realizes the domain ontology construction of the atlas, but this is only a link in the process of atlas construction, and the next step needs to be labeled and extracted from the data, which is not narrated due to the content limitation. Knowledge graph is a very powerful data integration tool, the future will be very helpful in the field of product design, to help designers realize rapid design inspiration organization, improve design efficiency, assist designers in secondary design. The future of product design will be combined with artificial intelligence, the use of knowledge graph for design will also be a trend, with the assistance of knowledge graph, will provide greater help for designers.

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