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A Design Knowledge Management Method for Car Cockpit Based on Hidden Markov Model

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Abstract:

Digital Twin, big data, cloud services and artificial intelligence are subverting the existing automobile design and manufacturing industry process, and making it develop in the direction of Agility, digitization and intelligence. However, limited by the differences in the design level of individual designers and the complexity of design activities, it is difficult to improve the efficiency of automobile design in design process. This study analyzed the characteristics of the car cockpit design knowledge and studied the expression pattern of the cockpit design knowledge, and then applied the knowledge mapping method to form the knowledge feature after car cock-pit design knowledge modeling. Finally, a knowledge management method for cockpit collaborative design based on the Hidden Markov Model (HMM) was proposed. This method introduced the history design knowledge of existing automotive cockpit cases into the design and solution of new project design problems. The research result proved that this method can help automobile designers quickly retrieve the design information needed for product design and process management, thus greatly improving design efficiency.

Keywords*: Car cockpit, Design expression, Design Knowledge management, Collaborative design, Hidden Markov Model (HMM)*

I. INTRODUCTION

With the impact of electric vehicles, automated vehicles, and Internet of Vehicles (IoV), it is expected that the development and profit model of traditional automobile manufacturers will be challenged[1], and the user experience of the car cockpit is also highly concerned[2]. The ecosystem of the automobile industry is facing a great change, which has become a consensus[3]. The relationships between the intelligent system and human, human and information in the intelligent car cockpit are becoming more and more complex, which lead to the diversification of human behaviors and interactions in the car[4]. The car cockpit is an important scenario for the users to interact with the car[5], and also an important part of automotive product design and user experience, which involves far more extensive, complicated and influential design knowledge and constraints than car exteriors. The design activity of intelligent car cockpit is surpassing the modeling design of automobile exterior design and becoming the key design content that directly affects the user experience in the car[6]. Automobile design information is not only the carrier of design, but also an influential digital asset of automotive original equipment manufacturers (OEMs).

At present, the reality facing the automobile manufacturing industry is that a massive, fragmented, multi-scene digital information environment in the process of automotive design[7]. In the transformation and upgrading of automotive design and manufacturing, a complete knowledge management system is of great importance, and the key to supporting enterprises in the aspects of agile development, accelerated order delivery and improved user experience. It is also widely believed that a company's valid application of its design knowledge is indispensable to the sustainability of competitive advantages[8]. As a result, the effective management of car cockpit design knowledge contribute significantly to improving the efficiency of car design and manufacturing, user experience improvement, and shortening the product development cycle[9-12].

Digital twin, big data, cloud services and artificial intelligence are subverting the existing automotive design and manufacturing industry processes[13-16], making it more agile, digital, sustainable and intelligent[17]. Previous studies have extensively excavated different directions and aspects relating to the knowledge management in product development[3, 9, 18-23]. J. Pinheiro et al. proved that knowledge creation affects the overall operation and business performance of the company through many links of design and manufacturing[24]. Different types of technical data of design and manufacturing are not stored in a unified knowledge management platform[25], Therefore, the problem is how to effectively manage and reuse the knowledge gained from previous product development [25]. Meanwhile, it is also an important part of intelligent manufacturing to share and use technical and empirical knowledge in the decision-making process, so as to transform traditional enterprise into intelligent and digital enterprise. M. B. Ahmed et al. proposed an intelligent virtual system to collect, store, and use industrial and engineering knowledge from manufacturing process[9]. P. Schott et al. proposed a reasoning system based on historical cases to systematically promote knowledge transfer in complexity management process[26]. Y. Wang put forward a design knowledge management framework for aircraft cabin to improve the accuracy and availability of knowledge matching in the process of aircraft cabin design and manufacturing [27]. P. Cocca et al. developed an data-based system to increase the effectively implementing of knowledge management in the business domain[28]. Existing research on knowledge management has made some progress in the field of knowledge transfer during manufacturing and specific knowledge support platforms in the context of intelligent manufacturing [19, 29].

However, there are still many enterprises and studies that underestimate the important assets that create value, that is, their past design experience and design knowledge, especially in car industry [30-32]. The construction of a design knowledge management system helps to create an information incremental ecosystem in the automotive design and manufacturing industry so that participants in all aspects of the product design process become information contributors, enablers and beneficiaries[33-35]. Car cockpit involves many automobile components, and its design is a work of intensive knowledge. Only with effective design knowledge management system, can the digital collection, acquisition, arrangement and storage of design knowledge be realized [36-38], and then can the digital design knowledge collaboration

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be realized between car cockpit product design and intelligent manufacturing[7, 39]. However, restricted by the differences of design standards, principles, documents and other design knowledge in different design and development stages, it is difficult to share and reuse car cockpit design knowledge in different design stages[40-42]. In consequence, there are still many technical and methodological problems in developing an efficient, practical and intelligent car cockpit design knowledge management system to support targeted design knowledge capturing and management in each stage[40, 43, 44].

Given the above problems, the design knowledge circulation mode between researchers, decision-makers, designers and engineers in the product development process of car cockpit was analyzed. Moreover, with the dimensions of car cockpit design knowledge as the basis, a semantic mapping model of car cockpit design knowledge was constructed, and a data-based knowledge design management system of car cockpit, which based on the Hidden Markov Model (HMM) was proposed, aiming to improve design efficiency and support the effective management of car cockpit collaborative design in the context of intelligent manufacturing and Industrial 4.0.

This research is organized as follows. Section 2 provides design knowledge modeling of car cockpit design. Section 3 presents a mapping model of car cockpit design to calculate the matching degree of knowledge element retrieval. Section 4 elaborates the HMM model and a case application of the model is introduced. Finally, conclusions and discussions of this paper are presented in section 5.

II. CAR COCKPIT DESIGN KNOWLEDGE MODELING

The design and development of car cockpit require several stages of design, modification, optimization and feedback, and finally form a digital prototype which can be used for digital manufacturing[45, 46]. In addition to an rapid and effective co-design mechanism in collaborative environment, it is crucial to obtain the required design knowledge data at one time to support engineers and designers to acquire more targeted design knowledge in the whole process of design and manufacturing[47-50]. The key factors that designers should consider are the interior design of car cockpit, ergonomics in design that affect users' comfortable experience and car cockpit layout. In this paper, the overall design knowledge system of car cockpit is divided into design knowledge in car cockpit design, layout and human factors.

2.1 Design knowledge in car cockpit design

The overall design process of car cockpit involves design activities and organization and coordination between engineers and designers. It contains not only the design process knowledge in various design stages, such as design task coordination, design intent and design allocation knowledge, but also organization knowledge and design knowledge ontology such as system integration environment. Process knowledge is the logic thinking knowledge that designers solve design problems.

Through the application of historical knowledge of design cases, complicated and fuzzy design process knowledge can be digitalized through logic relationships and task coordination and allocation, and the

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knowledge information in the whole design process will be stored in the database of historical design knowledge. Due to the complexity of product design and design process[51], collaborative design process itself also needs to be managed and modeled. Design process knowledge can be reused and developed as the collaborative design process knowledge of a new series product development, and the knowledge base of system integration process models can be built through its association with the design knowledge of various knowledge activities[39, 52, 53].

The composition of design organization knowledge is characterized by distributed environment, rapid knowledge renewal, diversified forms of knowledge, system user orientation, etc. In the data driven collaborative design knowledge platform [48], the characters of design knowledge itself and the end-users of knowledge determine how various knowledge is expressed and how those expressions are organized. The subject of design knowledge includes user subject knowledge and designer subject knowledge. User subject knowledge includes design knowledge information such as user requirement, user emotional indicators, user experience and user scenario. Designer subject knowledge includes implicit design knowledge of subjective, fuzzy and descriptive nature such as designers' ideas, experience, skills and inspirations, and definite knowledge of design, such as design reports, datasets, documents, regulations, standards and design manuals [54, 55].

2.2 Design knowledge of car cockpit layout

The car cockpit layout is closely related to users' comfortable experience, safety and economic benefits. However, there are many constraints, and the factors affecting and containing car cockpit layout are fairly complicated. The design knowledge of car cockpit layout mainly involves interior layout and human-machine interface (HMI) layout[56].

The design knowledge of car cockpit interior layout includes that of interior aesthetic principles (unity and change, symmetry and balance, contrast and harmony, etc.), modeling function layout, color layout (color matching, color trend, color relations, etc.), material layout (material classification, material design expression, etc.) and seat arrangement.

HMI is an important medium for interaction between human and vehicle[57]. A favorable HMI layout design is crucial to improve the overall driving experience and safety[58]. The design knowledge of HMI layout mainly involves that of dashboard layout, steering wheel control button layout, central control interface layout, physical interface layout of the central console, etc.

2.3 Design knowledge of car cockpit ergonomics

Car cockpit is an important place where driving behaviors and human-vehicle interaction occur. Therefore, the considerations of driver or passenger human factors, ergonomics and comfort are quite important. The design knowledge of car cockpit ergonomics mainly contains that of car cockpit ergonomics data, seat comfort and driving safety ergonomics.

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The design knowledge of car cockpit ergonomics data mainly involves that of static and dynamic dimensions of human body (standing and sitting height, longitudinal and transverse arm span, activity space, etc.), and the design data of human body dimensions related to field of vision and reachable domain. The design knowledge of seat comfort mainly comprises that of seat size (height, breadth and depth), seat distance comfort (seat spacing, layout, etc.) and seat material comfort. And the design knowledge of driving safety ergonomics includes that of control gear ergonomics that affect driving safety.

III. CASE BASED CAR COCKPIT DESIGN KNOWLEDGE MANAGEMENT AND MAPPING

3.1 Management Level of Car Cockpit Design Knowledge

In the design and development of car cockpit, various organizations are involved. There will be a sufficient amount of knowledge and information generated during inter-organizational communication and product development, and the management process of design is a process of design knowledge instantiation. The premise for the construction of an overall design environment is always the unified modeling of car cockpit design knowledge. To this end, it is necessary to carry out appropriate encapsulation according to different original data forms to better integrate collaborative software systems. Therefore, an essential link is to associate, handle and cooperate the knowledge with car cockpit design data management system. According to the principles and features of distributed technology in configuring and operating different network nodes, a typical three-layer distributed system architecture is proposed as shown in Figure 1, which comprises data layer, function layer and application layer.

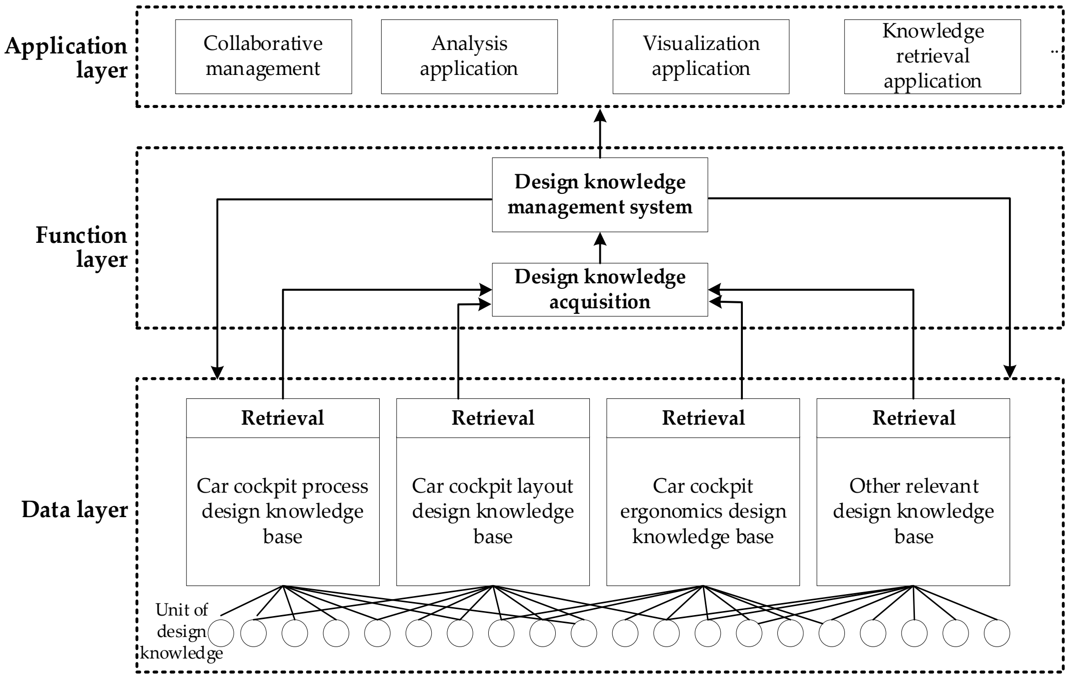

Fig 1. Design knowledge management level of car cockpit.

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The data layer represents the key design knowledge information in the database, and the data layer is the basic unit of the knowledge management system. This layer is designed to explicit the primitive properties of design knowledge elements in the most general level, allowing design knowledge to be extracted and applied in the collaborative semantic context. The implicit and explicit design knowledge acquired from different historical design cases, knowledge processing technologies and other sources can be used to serve the function and application layer. The data layer of design knowledge is constructed to define the content of basic design knowledge, thereby supporting the knowledge classification of quantifiable units that describe design knowledge.

The function layer is the principal part of the car cockpit design management system and the bridge between the data layer and the application layer. After the car cockpit design knowledge base is constructed, a knowledge classification system is established and design knowledge management tools are developed, which facilitates the timely retrieval and reuse of design knowledge. All the data will be acquired from the database, and the updated data will be stored in the database again. In addition, as the link between different modules of the data layer and the application layer, the function layer is responsible for the interaction and coordination of the whole collaborative environment, and organically combines separate and dispersive car cockpit design knowledge.

The application layer is the outmost layer of the entire distributed system architecture and directly interacts with the system user. This layer mainly comprises a variety of tools and software used in general design knowledge management. The platform users request data from the database and uses the function provided to conduct data analysis and processing, and finally returns the result to the data layer. As the function media of the car cockpit design knowledge management system, the application layer presents certain practical functions for the whole knowledge management process of collaborative design.

In the design and production process of previous models, car companies have produced many historical design cases, which carry a great deal of design knowledge with great reference value and guiding significance. Through the association and matching between the design knowledge in historical cases of car cockpit and the specific design process, it is ensured that designers can easily and accurately obtain and use case knowledge resources related to the current design tasks during collaborative design. In knowledge management and matching, the matching quality can be improved to the maximum extent through the knowledge matching based on project time and content, and more accurate and usable design knowledge is transmitted to the users to improve the design efficiency, thereby effectively shortening the design cycle.

3.2 Design Knowledge Management of Design Process in Historical Cases of Previous Models

In the design and production process of previous models, car companies have produced many historical design cases, which carry a great deal of design knowledge with great reference value and guiding significance. Through the association and matching between the design knowledge in historical cases of car cockpit and the specific design process, it is guaranteed that the case knowledge data related to the

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current design project can be easily and accurately obtain and reuse by the designers during collaborative development of new product.

As can be seen from Figure 2, in knowledge management and matching, the matching quality can be improved to the maximum extent through the knowledge matching based on project time and content, and more accurate and usable design knowledge is transmitted to the users to improve the design efficiency, thereby effectively shortening the design cycle. In the product design development process, the knowledge management of different design cases is of positive significance to the system itself. At different time nodes, system users, decision makers, designers, engineers allow to extract the matching design knowledge from the case knowledge chain in that domain to complete collaborative design activities, and finally cooperate with and support the entire collaborative design process.

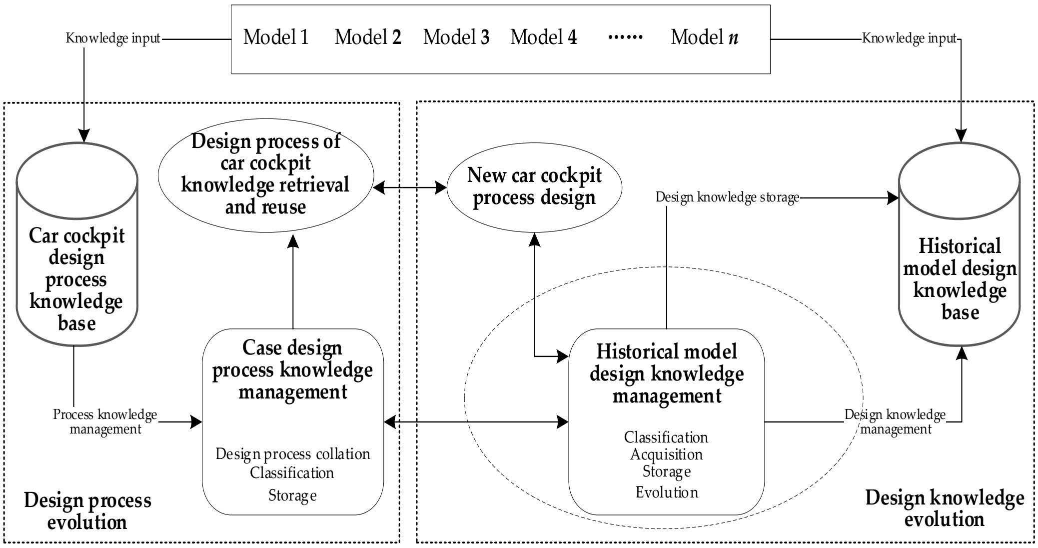

Fig 2. Design process management of historical case of car cockpit.

3.3 Car Cockpit Design Knowledge Mapping

Compared with car exteriors, the design knowledge involved in the design of car cockpit is far more extensive and complicated[57]. The car cockpit design project of previous models is the carrier of design knowledge, and contains implicit knowledge and default consensus which are difficult to be expressed in words and may be encountered in the development of new projects. In addition, the historical design cases of car cockpit are applied to transmit design experience and various design information in the design process, which can promote the knowledge circulation in the design information flow, so that relevant designers and engineers can quickly acquire useful information, and that the opportunity for expanding and innovating car cockpit design knowledge is increased.

As shown in Figure3, the mapping of historical car cockpit design knowledge can be regarded as a design knowledge mapping framework composed of design process domain P_V, process knowledge ontology F_C, layout design knowledge L_U, ergonomics design knowledge E_V and other design knowledge

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Z_V. Process domain P_V represents the knowledge involved in the design processes of historical design projects, while layout design knowledge L_U, ergonomics design knowledge E_W and other design knowledge Z_V represent different kinds of design knowledge sets.

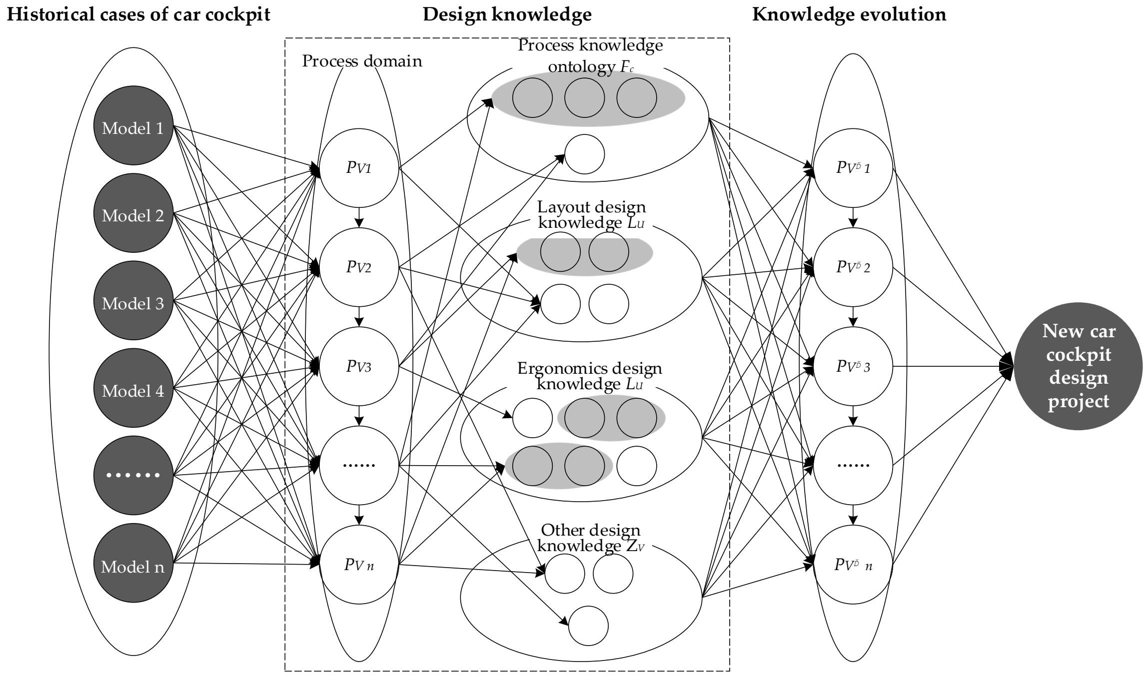

Fig 3. Domain design case driven design knowledge mapping method.

To facilitate relevant designers and engineers to quickly acquire useful design information, a mapping is created based on historical cases, design knowledge and new design projects of car cockpit. The classified design knowledge sets can be expressed mathematically as follows:

1) Process domain P_V in design knowledge.

The design process of car cockpit covers the whole process from the creative design stage to the final mass production of finished vehicles. The process domain P_V embodies the evolution and iteration of design knowledge under the time sequence. It mainly consists of creative design stage P_{V1}, detailed design stage P_{V2}, prototype stage P_{V3}, mass production stage P_{V4} and other segmented processes, as well as detailed elements in the product design process. Therefore, the process domain is denoted as $P_V= \{P_{Vi}, i=1, 2, ..., n\}$.

2) Process knowledge ontology Fc.

Process knowledge ontology Fc mainly focuses on the design process knowledge F_{c1}, design organization knowledge F_{c2}, design knowledge ontology F_{c3}, design knowledge F_{c4} that may be used in other processes of the car cockpit. Therefore, it is denoted as $Fc= \{F_{ci}, i=1, 2, ..., n\}$.

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3) Layout design knowledge LU.

The layout design knowledge of car cockpit mainly includes interior aesthetics design knowledge L_{U1}, modelling function layout design knowledge L_{U2}, color layout design knowledge L_{U3}, material layout design knowledge L_{U4}, seat layout design knowledge L_{U5}, HMI layout L_{U6}, etc. Therefore, it is denoted as $L_U= \{L_{Ui}, i=1, 2, \dots, n\}$.

4) Ergonomics design knowledge EW.

The ergonomics design knowledge EW of car cockpit mainly involves that of static and dynamic dimensions of human body EW_1, field of vision and reachable domain E_{W2}, seat comfort EW_3 and driving safety ergonomics EW_4. Therefore, it is denoted as $EW=\{E_{Wi}, i=1, 2, ..., n\}$.

5) Other relevant design knowledge ZV.

In the design and development process of car cockpit, a great deal of other design knowledge will be utilized, which is denoted as $Z_V=\{Z_{Vi}, i=1, 2, ..., n\}$.

The process domain PV, process knowledge ontology F_C, layout design knowledge L_U, ergonomics design knowledge E_V and other design knowledge Z_V in the historical project cases of car cockpit can be collated, filtered and reused to help designers quickly find the design knowledge based on the design process schedule and perform rapid design and development.

IV. HMM BASED CAR COCKPIT DESIGN KNOWLEDGE EXTRACTION ALGORITHM AND ITS IMPLEMENTATION

The advantages of HMM lie not only in modeling the unobservable states and the functional relationships between unobservable states and observable associated variables, but also in its natural advantages in transferring time series[59]. The design knowledge elements with the highest probability of matching are pushed to designers or other users by virtue of the HMM model, thereby achieving efficient design knowledge extraction and reuse, which plays a decisive role in improving the efficiency of car cockpit design knowledge management.

4.1 Parametric Definitions of HMM

The design knowledge data in P_V, F_C, L_U, E_W and Z_V of the historical project cases of car cockpit can be considered as a knowledge element that contains textual information description, and the extraction and application of design knowledge units in these cases can be implemented based on the detection of the text similarity between the knowledge elements. Based on the process domain P_V of the knowledge series containing time features, the textual information matching is calculated in F_V, L_U, E_W and Z_V. HMM is expressed as $\lambda= \{N ,M ,A ,B ,\pi\}$, of which the parameters are defined as follows:

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1) HMM contains state-dependent design process knowledge, and product design process exists as a kind of time series knowledge, which runs through the entire life cycle from concept generating to product launching. Specifically, N represents the N time-tag states of design knowledge units in the process domain P_V, which can be denoted as $\{P_{V1}, P_{V2}, P_{V3}, ..., P_{VN}\}$. At time t, the state of Hidden Markov Chain is qt, and qt$\in\{ P_{V1}, P_{V2}, P_{V3}, ..., P_{VN} \}$ is true.

2) M represents the number of design knowledge sets contained in F_C, L_U, E_W and Z_V, and the symbol set is denoted as $K =\{k_1, k_2, ..., k_M\}$.

3) The probability matrix of design process knowledge state transition is A = {aij}, $1 \leq i \leq N$, $1\leq j \leq N$, of which aij =P(qt =sj|qt -1 =si), $\sum_{j=1}^{N} a_{ij} =1$, $1 \leq i \leq N$, $1 \leq j \leq N$, aij ≥ 0.

4) The probability matrix of design knowledge output is B = {bik}, $1 \leq i \leq N$, $1\leq k \leq M$. bik =P(Ot =vk |qt =si), $\sum_{K=1}^{N} a_k =1$, $1 \leq i \leq N$, $1 \leq k \leq M$, b ik ≥ 0.

5) The probability distribution of the initial state is $\pi= \{\pi 1, \pi 2, ...,\pi N\}$, of which πi =P(X 1 =si), $\sum_{i=1}^{N} \pi i=1$, $1 \leq i \leq N$, $\pi i \geq 0$.

4.2 HMM Based Car Cockpit Design Knowledge Extraction Method

The HMM model related to car cockpit design knowledge extraction is constructed to search the keyword sequence $W = \{w_1, w_2, w_3, ..., w_n\}$, and to determine the final output part-of-speech sequence $Q =\{q_1, q_2, ..., q_n\}$, which maximizes P(Q|W). Meanwhile, the corresponding design knowledge will be first pushed to the users.

As for the text annotation of design knowledge units, it is required to determine and complete the text annotation of the number of design knowledge sets contained in the HMM model based on the initial setting of the process domain P_V. The text tag sequence of design knowledge units is taken as the hidden state, while the input key words or sentences for retrieval are taken as observation symbol, which are sorted according to the size of P(Q|W) and pushed to the users. In this paper, the HMM model is constructed with the maximum likelihood (ML) algorithm, and the specific training process of the model is conducted in two steps:

Based on statistical methods, the specific parameters of the HMM model are obtained from the car cockpit design knowledge base sample.

The design knowledge units of the car cockpit design knowledge base require complete textual information description which is based on the time sequence of process domain P_V. The descriptive statements are broken down into sequences composed of keywords. According to the formulas below, the initial state probability, transition state probability and state release probability are calculated.

$$\pi i = \frac{\text{Init(i)}}{\sum_{j=1}^{N} \text{Init(j)}}, 1 \leq i \leq N \tag{1}$$

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Init(i) represents the number of sequences with the initial state i in the training sequence with the basic unit of keywords in the descriptive text of design knowledge units.

$$aij = \frac{Cij}{\sum_{k=1}^{N} Cik}, 1 \leq i,j \leq N \tag{2}$$

Ci,j represents the number of transitions from state Si to state Sj in all training sequences.

$$B\,j\,(Vk) = \frac{Ej(Vk)}{\sum_{i=1}^{M} Ej(Vi)}, 1 \leq j \leq N, 1 \leq k \leq M \tag{3}$$

Ej(Vk) represents the number of times that state Sj releases keyword V_k in all training sequences with the keyword in the design knowledge text as the basic unit.

The HMM model constructed is used to perform rapid design knowledge extraction.

No matter for keyword retrieval or descriptive statement retrieval of design knowledge, this algorithm splits descriptive statement into keyword sequences, of which the release probability is the sum of that of keywords in that sequence. For the keyword sequence $O=\{O_1,O_2\ldots O_T\}$, if the length of the t^{th} block is K (containing K design knowledge keywords), it is denoted as Ot_1, Ot_2, ..., Ot_K, then the probability that state j release the t^{th} block is:

$$bj(Ot) = \sum_{k=1}^{k} bj\,(Otk) \tag{4}$$

With the block sequence $\{O_1, O_2\ldots O_T\}$ as the model input, the state sequence with the maximum probability is determined by Viterbi algorithm, and the best-matched car cockpit design knowledge is pushed according to that sequence.

4.3 Algorithm Effectiveness and Evaluation

To verify the practical value of the algorithm, the design knowledge in three design cases of car cockpit is sorted out and described for textual information, and then stored in the case design knowledge base. The three design cases come from 3 design schemes of new car brands in China. The most obvious feature of the three products are intelligence and electrification. The similarity of 3 design schemes is that the cockpit screen is large and has many new interaction technologies, such as gesture interaction, voice interaction and fatigue detection. In addition, the differences between the three car cockpits lie in the size of the central control panel, the layout of the interior and the details of human factors engineering. Five design experts are invited to verify the algorithm. The matching rate between HMM model and traditional keyword retrieval is compared[59, 60]. The results of matching test are expressed by the matching rate of keywords, ranging from 0 to 1. The satisfaction range of the five design experts is 0-10, with 10 being the most satisfactory.

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TABLE I. COMPARISON OF MATCHING DEGREE AND SATISFACTION RESULTS OF CAR COCKPIT DESIGN KNOWLEDGE RETRIEVAL.

Number of Keywords		1	3	5	7
HMM	Matching rate	0.90	0.93	0.95	0.96
	Satisfaction	7	7.5	8	8
Keyword retrieval	Matching rate	0.90	0.65	0.40	0.10
	Satisfaction	8	6.5	4	1

As shown in Table I, when the number of keywords is 1 (sketches), the two methods achieve a similar matching rate, while the keyword retrieval method has slightly superior satisfaction. When the number of keywords is greater than 5((sketches, Modularity, interior decoration, instrument cluster, UI), the matching rate of design knowledge is poor for traditional keyword retrieval method, and its satisfaction is also far lower than that of the HMM model. With the increase of keywords contained in the design knowledge text, the knowledge matching rate of HMM model is higher and tends to be stable, with higher satisfaction of design knowledge. In contrast, the matching rate and satisfaction of traditional keyword retrieval method tend to be worse. There is often more than one keyword in the text description of knowledge retrieval in the car cockpit design knowledge management. As can be seen from the table below, HMM model can index and push the best-matched design knowledge to designers or engineers, and help them obtain the key design information in real time to the greatest extent, thereby shortening the design and development cycle.

V. DISCUSSIONS

At present, the emerging intelligent interaction technology is breaking the traditional car cabin design and integrating more digital content into the cabin design[61]. Therefore, the first research problem to be solved in this paper is to sort out the knowledge of cockpit design and manufacturing. In this process, in addition to the traditional industrial design knowledge, the research mainly focuses on the design knowledge about human factors related to the intelligent experience and the design and manufacturing knowledge related to sustainability. The purpose of combing and modeling the design knowledge in this research is to sort out the design knowledge most related to the intelligent experience of users, to provide a knowledge base for the agile development of the cabin and improve the efficiency of design iteration.

In the design and development process of automobile cockpit, different organizations are involved, which will produce a lot of information and knowledge. The unified modeling of automobile cockpit design knowledge is the premise of the construction of the overall design environment. Therefore, it is necessary to properly seal according to different original data forms to better integrate heterogeneous software modules. It provides a knowledge base for knowledge management in the whole lifecycle, and is conducive to the effective use of design knowledge management system by all departments.

To improve the matching accuracy of knowledge extraction, this study introduces the HMM model, which can take the time variable in the design and manufacturing process as an important variable to model the functional relationship between the unobservable state and the unobservable state and the measurable related variables, so that the design knowledge element with the highest matching probability can be pushed to designers or other users to achieve efficient design knowledge extraction and reuse, which plays a decisive role in improving the efficiency of automobile cockpit design knowledge management. The contrast test shows that the HMM method has a higher knowledge matching rate and satisfaction than the traditional keyword retrieval method, and can effectively support the design knowledge extraction and application of designers, thus improving sustainable performance of automotive OEMs.

VI. CONCLUSIONS

In this paper, the problem in car cockpit design knowledge management of automobile manufacturers is studied, and a Hidden Markov Model is proposed to support knowledge extraction. According to the features of car cockpit design knowledge, key information that affects the expression of car cockpit design knowledge is summarized, and the car cockpit design knowledge is modeled. Through the mapping of historical car cockpit design cases with design knowledge in new car cockpit project design and development, the hidden Markov parametric method is utilized to assist the knowledge extraction and management of car cockpit designers.

The method introduces the design knowledge of the existing car cockpit cases into the solutions for the design problems of new projects, and enables the car interior designers to quickly search all the design information required in product design development and process management, thereby shortening the whole product development cycle.

In addition to the contributions, this study also has some limitations. Firstly, the present study mainly proposes a new knowledge extraction algorithm to improve the efficiency of automobile cockpit design and manufacturing, but the enterprise's design knowledge is scattered and the file format is diversified, so a platform for unified management is needed to manage complex design and manufacturing knowledge by building a knowledge management cloud service platform and combining with new knowledge extraction algorithms. Secondly, the current research object is mainly about the design and manufacturing knowledge of the automobile cockpit, and future studies could develop a design knowledge management platform for the whole automobile life cycle to maximize the sustainable development of the organization and society.

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