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Intelligent Costume Recommendation System Based on Expert System

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Abstract: On the basis of expert system, we design a costume recommendation system which provides customers with clothing collocation solution and more experience. We set up a costume matching knowledge base collected from experts, and represent the knowledge with production rules. By analyzing the customers' specific physical information got through man-machine interface, the proposed system provides customers an intelligent costume recommendation strategy in accordance with blackboard model reasoning. Moreover, index adding algorithm is integrated into the traditional serial blackboard model in the system. Finally, we present experiments which show the search rate is improved significantly.

Key words: costume recommendation, expert system, blackboard model, index adding
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0 Introduction

In recent years, online sales of costume are more and more popular with the rapid development of the global economy and communication. At the same time, the return rate is rising continuously[1]. The possible reason is that consumers cannot try the clothes, so it is difficult for them to judge whether the costumes are suitable or not. In this circumstance, the customers keep a wait-and-see attitude and feel hard to make a purchase decision, which reduces the trust and loyalty for online costume sales eventually.

At present, the major achievement of online costume recommendation is the recommendation based on establishing size and 3D simulation[2-4]. For example, a recommendation system named "right size" adopts the technology of "Rosetta stone" to recommend costume size. The model in the virtual fitting room can change the figure and simulate the customer according to the personal information. Then the customer can choose his favorite costumes and put them on the model to see the fitting effect. The disadvantage is that the system only offers the online fitting, not the specific costume recommendation. What's more, the virtual model is not able to replace the real figure completely. In China, Zheng Aihua's team applied the back propagation (BP) neural network to the costume size recommendation. She took the figure data as the input of the BP neural network and then output the corresponding size. Numerous samples were trained in the network to obtain the corresponding output. Finally, it realized the costume size recommendation through setting the trained threshold values and weights. But the system does not consider the costume style recommendation, which is a bit difficult to achieve satisfactory effect. Liao Chen's team put forward the virtual dressing room system based on the cloud platform. They adopted the technology of big data and collaborative filtering algorithm to predict the customers' clothing interests. This costume recommendation system is not widely used due to high requirements for hardware. In addition, the recommendation scheme of the system is similar to the popular websites such as Amazon, Tmall and Taobao. The recommend products are the same types as what the customers buy or search. These systems simply recommend costumes in accordance with the customer's interests and purchasing behaviors, not considering the actual appearance of the customer and the experts' experience.

In this paper, we propose a costume recommendation system based on expert system, which provides customers clothing collocation solution. The expert system first imitates how experts solve specific problems in the inner thought process, and then applies

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artificial intelligence techniques to solve these problems according to numerous knowledge and experts' experiences[5-6]. The process of the proposed costume recommendation system is as follows: firstly, it acquires the customers' specific physical information via man-machine interface; secondly, it sets up costume matching knowledge base collected from the experts, and represents the experts' costume matching knowledge with production rules; finally, it provides customers an intelligent and efficient costume recommendation method in accordance with modified blackboard model reasoning. The system provides the customers more personalized and professional costume recommendation based on the customers' external physical traits (skin-color, body-shape, face-shape, shoulder-shape) and the costume matching knowledge from fashion experts; the index adding blackboard model reasoning can improve the search rate of the system.

1 Structure and Principle of the Costume Recommendation System Based on Expert System

There are five parts in the proposed costume recommendation system: human-machine interface, knowledge base, inference engine, knowledge acquisition mechanism and explanation mechanism, as shown in Fig. 1. The knowledge base acquires the knowledge through knowledge acquisition mechanism, which includes fact base and rule base. The fact base mainly stores the costume information of the on sell clothing, such as costume-color and costume-style[7]. The rule base mainly stores costume matching knowledge acquired from the fashion experts and researchers. The inference engine is a component of the expert system based on knowledge inference, and it aims to simulate the thought process of fashion experts[8]. The inference engine can search and query the specific target according to the reasoning mechanism and the established inference rules. The common reasoning mechanism of the expert system includes the fuzzy inference model, the neural network inference model, the blackboard model and so on[9-10]. We consider the blackboard model and optimize it by adding the index to improve the working speed of inference engine.

The process of the costume recommendation system is presented as follows. Firstly, the system keeps interacting with the customers through the human-machine interface. For instance, the customers are asked to input their personal physical information such as skin-color, body-shape, face-shape and shoulder-shape. Secondly, the costume recommendation system invokes inference engine and constantly draws the conclusion from known information according to costume matching knowledge and the customers' facts. The matching knowledge is mainly based on the principle of costume-color and the costume-style knowledge. In order to find out the relationship between the physical figure and the costume-style, the information of body figure is divided into three classes: face-shape, shoulder-shape and body-shape. Specifically, face-shape and shoulder-shape determine the suitable collar-shape of the clothing and the body-shape determines the suitable costume-style[11]. The proposed system can search the suitable clothing collocation for the customer on the basis of the customer's skin-color and the body figure. Moreover, it stores the intermediate result into the knowledge base for further inference, and the unknown state of a problem is converted to a known state. Finally, the system searches the fact base for the on sell costume information in accordance with the result of inference engine. The system generates the final clothing recommendation result and gives the explanation through the explanation mechanism.

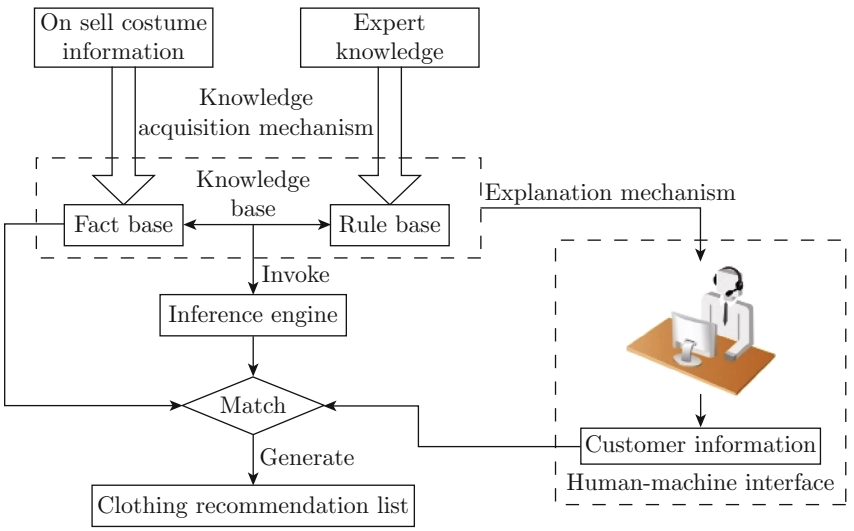

Fig. 1 Structure of the costume recommendation system based on expert system

2 Design of the Knowledge Base in the Costume Recommendation System

2.1 Structure of the Knowledge Base

The knowledge base of the costume recommendation system is the knowledge storage structure. It is used to collect the experts' experience and express it in the form of certain rules. The knowledge base includes fact base and rule base[12-13]. The fact base contains two kinds of information stored in the database. One part is the customers' personal information which includes skin-color, body-shape, face-shape, shoulder-shape, height, weight and so on. The other part is the on sell clothing information including costume-color, collar-shape, costume-style, etc. The rule base includes the rule table of costume matching (see Table 1) and the index table generated by optimizing the blackboard model (see Table 2)[14]. Figure 2 shows the structure of the knowledge base of the costume recommendation system.

Table 1 Rule table of the costume recommendation system

Rule	Rule condition (customers' characteristics)	Rule conclusion (information of on sell clothing)
1	White (skin-color)	White black, pink, orange, yellow, blue, navy, khaki (costume-color)
2	Partial black (skin-color)	Turquoise, purple, gray, blue, white, wine red (costume-color)
3	Partial yellow (skin-color)	Gray, green, red, black, orange, gold, white (costume-color)
4	Pink (skin-color)	Black white, gray, wine red, dark blue, dark green (costume-color)
5	Lean (body-shape)	Slim, free-size (costume-style)
6	Linear (body-shape)	Slim, free-size (costume-style)
7	Curved (body-shape)	Slim, free-size, loose (costume-style)
8	Obese (body-shape)	Free-size, loose (costume-style)
9	Round (face-shape)	V neck, standing collar, polo, high (collar-shape)
10	Oval (face-shape)	All (collar-shape)
11	Square (face-shape)	V neck, U neck, round (collar-shape)
12	Elongated (face-shape)	Square, round, high and horizontal (collar-shape)
13	Inverted triangle (face-shape)	Round, square, standing, high, polo, horizontal (collar-shape)
14	Diamond (face-shape)	All (collar-shape)
15	Broad (shoulder-shape)	V neck, U neck, deep round (collar-shape)
16	Narrow (shoulder-shape)	High, shallow round, horizontal, standing, polo (collar-shape)
17	Inclined (shoulder-shape)	High, shallow round, standing, polo (collar-shape)
18	Standard (shoulder-shape)	All (collar-shape)

Table 2 Index table of the blackboard model

Knowledge source classification	Rule condition	Rule conclusion	Satisfactory clothing quantity
Costume-color and skin-color collocation	White	White black, pink, orange, yellow, blue, navy, khaki	90
	Partial black	Turquoise, purple, gray, blue, white, wine red	67
	Partial yellow	Gray, green, red, black, orange, gold, white	108
	Pink	Black white, gray, wine red, dark blue, dark green	54
Costume-style and body-shape collocation	Lean shape	Slim, free-size	154
	Linear shape	Slim, free-size	154
	Curved shape	Slim, free-size, loose	200
	Obese shape	Free-size, loose	137
Costume collar-shape and face-shape collocation	Round face	V neck, standing collar, polo, high collar	68
	Oval face	All	200
	Square face	V neck, U neck, round collar	118
	Elongated face	Square, round, high and horizontal collar	82
	Inverted triangle	Round, square, standing, high, polo, horizontal collar	160
	Diamond face	All	200
Costume collar-shape and shoulder-shape collocation	Broad shoulder	V neck, U neck, deep round collar	78
	Narrow shoulder	High, shallow round, horizontal, standing, polo collar	103
	Inclined shoulder	High, shallow round, standing, polo collar	88
	Standard shoulder	All	200

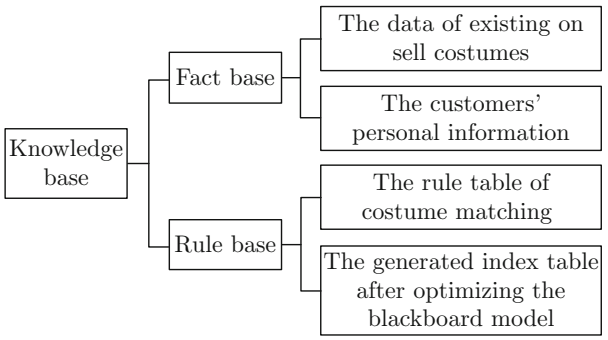

Fig. 2 Structure of the knowledge base

2.2 Acquisition and Presentation of the Costume Matching Knowledge

The acquisition of the costume matching knowledge is crucial to the recommendation system. The knowledge set influences the recommended result. The methods of knowledge acquisition are reviewed and can directly interact with the experts[15-16]. After numerous literature reviews and repeatedly talking with fashion experts, the system developing engineers integrate the costume matching knowledge and store it in the knowledge base.

Considering the large quantity of the costume matching knowledge, we present the production rule which usually indicates the causality correlation between the condition and the conclusion deduced from the condition[17]. The basic form of the production rule is presented as: if P then Q, which means the conclusion Q is deduced when the prerequisite P is satisfied. An example of production rule is: if face-shape is "round" and shoulder-shape is "X", then suitable collar-shape is "V"; here, the prerequisite P is that face-shape is "round" and shoulder-shape is "X", and the conclusion Q is that suitable collar-shape is "V". This rule shows the correlation between the customers' physical features and the neck pattern of the clothes.

2.3 Rule Table of the Costume Matching Knowledge

The proposed recommendation system focuses on the relation between the customers' physical characteristics and the costume information. The customers' physical characteristics are classified into skin-color, body-shape, face-shape and shoulder-shape. The skin-color is classified into white, partial black, partial yellow and pink. The body-shape is classified into lean shape, linear shape, curved shape and obese shape. The face-shape is divided into round, oval, square, elongation, inverted triangle and diamond. Table 3 gives some samples of the information on skin-color and body-shape. The costumes are classified by color, collar-shape and style in this paper. Table 4 shows parts of the classified information of on sell clothing.

Table 3 Samples of the classified information of the customers' physical characteristics

Physical characteristic		Description
Skin-color	White:	light white, no blush, pear white, smooth and delicate
	Partial black:	dark and gray skin color, wheat color, cool beige
	Pink:	white color, blush, pink-and-white color
Body-shape	Lean shape:	the weight is less than 20% of the standard weight
	Linear shape:	the weight floats within 20% of the standard weight, small differences in vital statistics
	Curved shape:	the weight floats within 20% of the standard weight, large differences in vital statistics
	Obese shape:	the weight is more than 20% of the standard weight

Note: the standard weight (kg) equals to (height (cm)−80)×70% for male, and (height (cm)−70)×60% for female, respectively.

Table 4 Parts of the classified information

No.	Color	Collar-shape	Style
1	Green	Round	Loose
2	White	Lapel	Slim
3	Pink	V neck	Loose
4	yellow	U neck	Slim
5	Black	Roll	Free-size
6	Gray	Wave	Slim
7	Camel	Round	Loose

The costume matching knowledge is collected from the experts' researches after finishing the classifications of the customers' physical characteristics and the on sell clothing information. The costume matching knowledge includes the matching costume-color with skin-color, the matching costume-style with body-shape and the matching collar-shape with face-shape. Then the rule base is established after transforming the costume matching knowledge into the computer machine language. The machine language refers to the form of production rule which means a conclusion can be deduced from a prerequisite. The rule table of the proposed costume recommendation system is shown in Table 1.

3 Realization of Inference Engine in the Costume Recommendation System

Inference engine is a component of the expert system based on knowledge inference[18]. In this paper,

blackboard model is selected as the reasoning mechanism of inference engine. The algorithm adopts forward inference to generate the rule conclusion from the rule prerequisite. Furthermore, the blackboard model algorithm is optimized with index adding so as to improve the searching efficiency.

3.1 Blackboard Model and Knowledge Source in the Costume Recommendation System

Blackboard model is a global database working area where recommendation information for reasoning is stored. Blackboard model is divided into different layers; each layer stores data used and revised by the knowledge source. Knowledge source consists of knowledge source condition and knowledge source action. Knowledge source condition is related to the blackboard information change, which means the judgment of events and knowledge source action is used to revise the blackboard information[19-20]. In the proposed recommendation system, knowledge source is divided into four parts: costume-color and skin-color collocation, costume-style and body-shape collocation, collar-shape and face-shape collocation, and collar-shape and shoulder-shape collocation, as shown in Fig. 3.

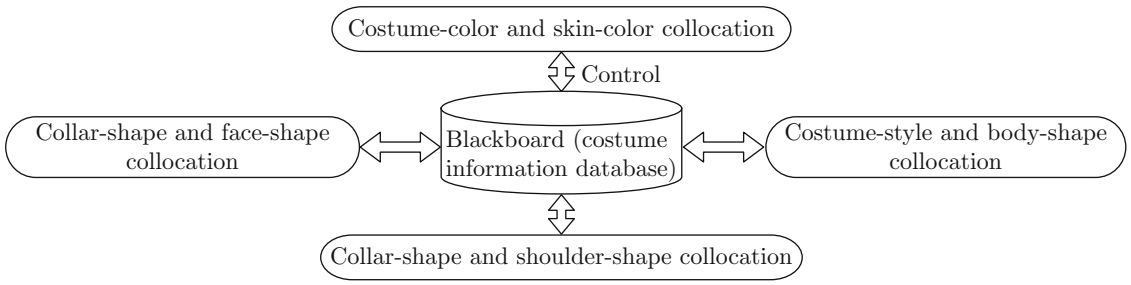

Fig. 3 Blackboard structure of the costume recommendation system

The knowledge source of traditional blackboard algorithm is in serial structure, which means the recommendation result in each layer is generated on the basis of the previous layer. Then the system stores the newly generated recommendation result as the input to the next layer until all knowledge sources are activated. The serial hierarchy structure of the traditional blackboard algorithm has flaws. Each knowledge source gets rule actions in accordance with the input conditions and calls the corresponding fact data in the blackboard (global database) to acquire clothing records. The scope of the database searched by knowledge source is based on its knowledge source of the previous layer. Therefore, the searching efficiency relies on the sequence of the knowledge source. For example, suppose that there are KS1 and KS2 in the global database blackboard. Then 10 data records are called by the rule action of KS1 while 4 data records are called by the rule action of KS2. The blackboard model first searches the 10 data records in KS1. Then it searches the second layer's result among the 10 data records. However, if KS2 is prior to KS1, the blackboard model first searches the 4 data records in KS2. Then it searches the first layer's result among the 4 data records. It not only reduces the quantity of queries, but also improves the searching efficiency. Therefore, sorting of the knowledge source is critical for optimizing the search algorithm.

3.2 Optimization of the Blackboard Model

The structure of blackboard model is optimized through index adding to improve the searching efficiency. The index is used to determine the priority of knowledge source. The steps of the improved blackboard model are presented as follows.

Step 1 Classify the knowledge source. In the costume recommendation system, recommendation is derived from costume-style, costume-color and collar-shape. The structure of blackboard model is shown in Fig. 3.

Step 2 Based on the above knowledge source classification and the costume matching knowledge, each knowledge source has different rule conditions and its corresponding conclusions. The index table is established after counting the number of clothes satisfying the rule table in Table 1. Table 2 shows the index table of the blackboard model in the experimental database in this paper. Detail information of the experimental case is shown in Section 4. Obviously, the satisfactory clothing quantity in each knowledge source varies with the on sell clothing. The established index table is one part of the intermediate data in the knowledge source of the costume recommendation system, as shown in Fig. 2.

Step 3 Each knowledge source obtains the corresponding rule conclusions in accordance with the conditions to solve the problem. Query the index table, and take each knowledge source as a function. Then n knowledge sources are represented as n functions, say, $f_1(x),\ f_2(x), \cdots,\ f_n(x)$, in which x is the parameter for the rule conditions. The function is the quantity of records which meets the requirement. After inputting a certain rule condition x_1, different knowledge sources respectively obtain the corresponding quantity of data records, say, $f_1(x_1),\ f_2(x_1), \cdots,\ f_n(x_1)$.

Step 4 Sort the numbers of records in a descending order, denoted as Desc$(\cdot)$, according to the priority of knowledge source layers. Therefore, the equation is represented as $g(x) = \text{Desc}(f_1(x), f_2(x), \cdots, f_n(x))$.

Step 5 Activate the actions of knowledge sources according to the priority of knowledge source in turn.

Step 6 Set the activation condition of the highest priority knowledge source as 1, and then search the blackboard database in forward reasoning strategy. Store the result as intermediate result into the next blackboard region and search the lower layer of knowledge source. Set the activation condition of the highest priority knowledge source as 0.

Step 7 Set the activation condition of next knowledge source as 1. Repeat the action in Step 6 until the last knowledge source. Find the recommendation result that meets each knowledge source.

The optimized blackboard model with index adding can dynamically determine the layers and the activation order of knowledge source according to the specific customer information. It improves the matching speed between the rule condition and the rule conclusion. Figure 4 illustrates the flow chart of the optimized blackboard model.

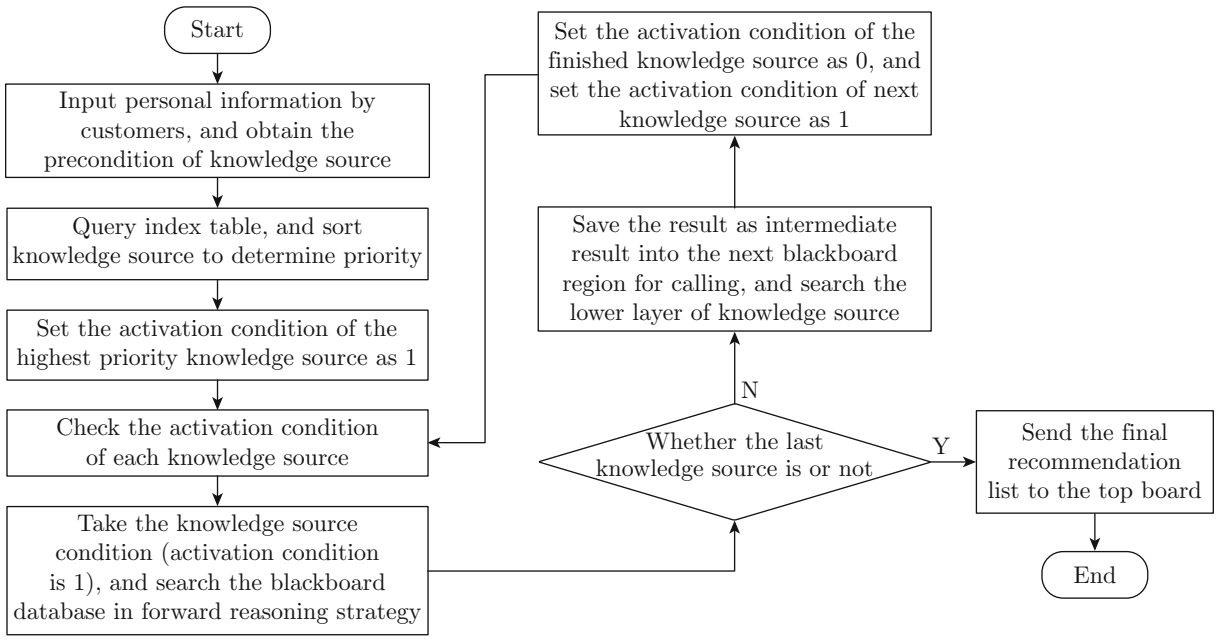

Fig. 4 Flow chart of the optimized blackboard structure

4 Practical Application of the Costume Recommendation System

Based on the structure of client/server, the proposed costume recommendation system is implemented with MySQL and Java language. Furthermore, experimental data are collected and input into the system as the customers' information, on sell costume information, costume matching knowledge, etc. The customers' information is collected from dozens of female volunteers. Totally 200 clothing datasets are mainly obtained from the websites of open clothing information and entity clothing stores. The brands are AZZURE, BURBERRY, ETAM, SISTERE, ONLY, VERSACE, etc.

The costume recommendation system applies the optimized blackboard model with index adding to search the recommendation result. An example for customers is taken. Suppose the customers' personal information is as follows: pink skin-color, linear body-shape, oval face-shape and narrow shoulder-shape. Set the information as the rule condition in Table 2. The satisfactory clothing quantity items for these four conditions are 54, 154, 200 and 103, respectively. Based on the optimized blackboard algorithms, the priority of knowledge source should be adjusted as: costume-color and skin-color collocation → costume collar-shape and shoulder-shape collocation → costume-style and body-shape collocation → costume collar-shape and face-shape collocation.

The recommendation system then activates each action of knowledge source in accordance with the priority. The result is obtained through searching the blackboard global database ultimately.

In order to compare the efficiency between the traditional and the optimized recommendation method, 4 sets of customers' information are input. Table 5 presents the recommendation result.

The system accesses the database according to the priority of each knowledge source and searches the on

sell clothes that match the rule conclusions. In the above table, the numbers of the on sell clothes satisfying the four users are 32, 14, 26 and 21, respectively. Regarding the first customer, the customer information (rule condition) is white skin-color, lean body-shape, inverted triangle face-shape and narrow shoulder-shape. Then based on the recommendation rules, the rule conclusions are set as follows: the suitable costume-colors are white black, pink, orange, yellow, blue, navy and khaki; the recommended costume-styles are slim and routine; the collar-shape might be round, square, standing, high, polo and horizontal. Then the recommendation system searches the on sell clothing information in the database to match the above conclusion. Figure 5 illustrates the recommended result for Customer 1.

Table 5 presents the satisfactory clothing quantity of each rule condition, lists the search priority of the traditional and the optimized blackboard model, and gives the comparison of the response time. Due to the adjusting of knowledge resource priority, the response speed using the blackboard model with index adding is quicker than that of the traditional one. The response time of the fourth customer is not shortened since the priority of knowledge source is not changed. The blackboard model with index adding is a dynamic process which can obtain different priorities according to the customers' information. It can search the satisfactory result in the knowledge source with the least quantity in the index table. Moreover, it sets the result in the former search as an intermediate scope to carry out the following search. The steps will be conducted until all four knowledge sources are searched. Since the search scope is optimized with the priority, the search speed of the recommendation is hence improved.

Table 5 The recommended result and comparison of the response time

No.	Customers' information (rule condition)	Satisfactory clothing quantity	Priority of knowledge source searching	Time/s	Numbers of satisfactory clothing (recommendation result)
1	White skin-color	90	Traditional: skin-color collocation (90) → body-shape collocation (152) → face-shape collocation (160) → shoulder-shape collocation (103)	4.3	32
	Lean shape	154			
	Inverted triangle face	160	Optimized: skin-color collocation (90) → shoulder-shape collocation (103) → body-shape collocation (152) → face-shape collocation (160)	3.6	
	Narrow shoulder	103			
2	Partial black skin-color	67	Traditional: skin-color collocation (67) → body-shape collocation (154) → face-shape collocation (200) → shoulder-shape collocation (78)	4.1	14
	Linear shape	154			
	Oval face	200	Optimized: skin-color collocation (67) → shoulder-shape collocation (78) → body-shape collocation (154) → face-shape collocation (200)	2.9	
	Broad shoulder	78			
3	Partial yellow skin-color	108	Traditional: skin-color collocation (108) → body-shape collocation (200) → face-shape collocation (82) → shoulder-shape collocation (88)	5.9	26
	Curved shape	200			
	Elongated face	82	Optimized: face-shape collocation (82) → shoulder-shape collocation (88) → skin-color collocation (108) → body-shape collocation (200)	3.1	
	Inclined shoulder	88			
4	Partial black skin-color	67	Traditional: skin-color collocation (67) → body-shape collocation (137) → face-shape collocation (200) → shoulder-shape collocation (200)	3.3	21
	Obese shape	173			
	Diamond face	200	Optimized: skin-color collocation (67) → body-shape collocation (137) → face-shape collocation (200) → shoulder-shape collocation (200)	3.3	
	Standard shoulder	200			

00022: white, slim, round collar | 00051: pink, slim, polo collar | 00026: blue, routine, square collar | 00029: khaki, routine, standing collar

Fig. 5 Recommendation costume information page for Customer 1

5 Conclusion

The costume recommendation system based on expert system designed in this paper aims to solve the subjective shortcomings of artificial clothing recommendation systems. The knowledge base in the proposed system stores the recommendation rules in the form of production rules, and the inference engine focuses on the blackboard model. This paper also proposes an optimization method of index adding to fasten the search speed of the recommendation result. Experimental implementation of the proposed system, using the data collected from the volunteers and the open websites, shows that the recommendation efficiency of the model is improved. One further direction is to update the knowledge base with intelligent acquisition method, and the customers' information in the system can also be broadened to the occupation, age, suitable occasions and so on.

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