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DEVELOPMENT OF AN EXPERT SYSTEM FOR CLOTHES STYLE SELECTION BASED ON KANSEI ENGINEERING

This research is devoted to implementation of the expert systems for rapid change in production of women's outerwear. Factorial analysis and the cluster analysis are used for the structuring of the subject environment.

Analysis of the emotional component of the garment on the basis of KE can be achieved through cluster analysis. Such an approach will identify models of clothes based on perception and emotional needs of the consumer.

Thus, the main goal of the study was achieved by forming decision-making rules aimed at solving the sub-task of selecting ready-to-wear models based on the Kansei Engineering methodology. The analysis and identification of the formed database of photos of ready-made clothing models was carried out by means of cluster analysis of intergroup relations using the Euclidean distance, which allows for the identification of conditional groups of relatedness of products by design attributes. The obtained final centers of the clusters together with the information about the color solution of the clothing models allowed us to build a product model of an expert system for choosing clothing that meets the formulated wishes of the target consumer.

The object of the study is the women's fashion dresses in spring-summer 2023 season. Thus, a general collection was formed which amounted to 66 photos of fashion dresses for subsequent questionnaire. Work with the software product takes place in the form of a dialogue in the form of consecutive system questions and user answers. The developed system can be used both for the selection of ready-made clothes (for example, in stores, including online stores), and for the selection of a prototype for the development of a new model of clothing that meets the aesthetic needs of the consumers.

Keywords: expert system, Kansei Engineering, consumers' needs, clothing model

КУЛЕШОВА СВІТЛАНА
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РОЗРОБКА ЕКСПЕРТНОЇ СИСТЕМИ ДЛЯ ВИБОРУ СТИЛЮ ОДЯГУ НА ОСНОВІ KANSEI ENGINEERING

Розроблена комп'ютерна архітектура експертної системи підтримки процесу адресного проєктування одягу в оболонці «Rapana», яка містить три бази даних (дизайн-атрибутів моделей одягу, зображень моделей одягу, дизайну і кольорів швейних виробів), базу знань, механізм виведення і інтерфейс споживача.

Основна мета дослідження була досягнута шляхом формування правил прийняття рішень, спрямованих на вирішення підзадачі вибору моделей готового одягу на основі методології Kansei Engineering.

Аналіз та ідентифікація сформованої бази даних фото готових моделей одягу виконана шляхом кластерного аналізу міжгрупових зв'язків із застосуванням евклідової відстані, що дозволяє виділяти умовні групи спорідненості виробів за дизайн-атрибутами. Отримані кінцеві центри кластерів у сукупності із інформацією про колірне вирішення моделей одягу дозволили побудувати продукційну модель експертної системи для вибору одягу, що відповідає сформульованим побажанням адресного споживача.

Робота з програмним продуктом відбувається у формі діалогу у вигляді послідовних запитань системи і відповідей користувача. Розроблена система може використовуватися як для підбору готового одягу (наприклад у магазинах, в тому числі он-лайн-магазинах), так і для вибору прототипу для розробки нової моделі одягу, що відповідає естетичним потребам споживача.

Ключові слова: експертна система, Kansei Engineering, потреби споживача, модель одягу

Problem statement

The clothing industry is quickly becoming a high-tech industry due to rapid advances in technology. High saturation of information environment and the risk of making wrong decisions increase the relevance of information technology as a means to support decision-making. Expert system is one of the most active and productive research in the artificial intelligence field now. Today, scientists in the world successfully implement elements of artificial intelligence and the expert system (ES) at various stages of designing clothes [1-9]. Kansei Engineering, which appeared in the 1970s, is committed to quantifying customers' psychological needs and transforming them into product design elements [1]. With the development of society and economy, consumers' needs become more and more personalized, so only to meet the needs of consumers can they occupy an advantage in the market [3, 9], especially in the clothing industry. Only by understanding the aesthetic needs of customers can precision marketing be carried out [10-13].

Analysis of the literature

Kansei Engineering can break the limitations of traditional methods and fully consider the psychological demands of consumers. With the deepening of research, scholars try to combine Kansei Engineering with other technologies to explore the potential needs of consumers better. At present, with the help of the method of Kansei Engineering, some scholars have studied the field of personalized recommendation [3,], functional design [6-9], women's suit vest design [2], e-commerce fabric retrieval [4], and fabric comfort [5].

The studies above transform the aesthetic and emotional needs of consumers into consideration elements in the process of fashion design or sales and achieve the purpose of improving customer satisfaction and meeting personalized needs, which can increase the competitiveness of clothing enterprises.

Aim of the work

The aim of this study is to implementation a prototype of the ES of the choice of clothes models based on

the assessment of consumers' emotional impressions using the methodology of Kansei Engineering (KE) [1, 2, 7, 8, 9-13].

Presenting main material

Analysis of the emotional component of the garment on the basis of KE can be achieved through cluster analysis. Such an approach will identify models of clothes based on perception and emotional needs of the consumer.

To perform the procedure of cluster analysis as a function of the distance between clothing models ρ(*Xp, Xq*) Euclidean distance is selected. Euclidean distance is usually represented by the formula of the traditional distance between two points, in this case, between two clothing models.

Then, if we take the notation of the set of clothing models – *X*, and each of the two clothing models – $Xp=(a_{p1}, a_{p2}, \ldots, a_{pn})$ та $Xq=(a_{q1}, a_{q2}, \ldots, a_{qn})$, were $a_1 = CS$ (Casual – Smart (clothes)), $a_2 = RS$ (Romantic – Sports (style)), $a_3 = CA$ (Classic – Avant-garde (style)), $a_4 = FM$ (Folk – Modern (clothes)), $a_5 = RO$ (Rectangular shape – Oval shape), $a_6 = TdTu$ (Trapezoid shape (long base down) – Trapezoid shape (long base up)), $a_7 = MP$ (Mono colour – Poly colours), $a_8 = BS$ (Bright – Soft (colour)), $a_9 = LD$ (Light – Deep (colour)), $a_{10} = WC$ (Warm – Cool (colour)), $a_{11} = MtPt$ (Mono texture clothes – Poly texture clothes), $a_{12} = MS$, $a_{13} = TN$ (Transparent – Non-transparent (texture)), $a_{14} = SA$ (Symmetry – Asymmetry).

The formula for calculating the Euclidean distance will take the form:

$$\rho(X_p, X_q) = \sqrt{\sum_{i=1}^{n} (a_{pi} - a_{qi})^2}, \quad (1)$$

where *Xp, Xq* – clothing models with conditional numbers *p*, *q*;
$a_{p1}, a_{p2}, \ldots, a_{pn}$ ($a_{q1}, a_{q2}, \ldots, a_{qn}$) – key design attributes of clothing models with conditional number *p* (*q*).
According to the formed bipolar scales [10, 11], the code of the each clothing models of the studied set should be represented as a tuple of 14 variables: *X*=(*CS*, *RS*, *CA*, *FM*, *RO*, *TdTu*, *MP*, *BS*, *LD*, *WC*, *MtPt*, *MS*, *TN*, *SA*).
Accordingly, for further clustering, the set of X clothing models is represented as:

$$X=(f_1, f_2, f_3, f_4, f_5, f_6), \quad (2)$$

were $f_1=f(SA, CA)$; $f_2=f(BS, LD, WC)$; $f_3=f(CS, MS, RS)$; $f_4=f(TN, MtPt)$; $f_5=f(FM, MP)$; $f_6=f(TdTu, RO)$.

Then the formula (1) for determining the Euclidean distance between two clothing models of takes the form:

$$\rho(X_p, X_q) = \sqrt{(f_{p1} - f_{q1})^2 + (f_{p2} - f_{q2})^2 + (f_{p3} - f_{q3})^2 + (f_{p4} - f_{q4})^2 + (f_{p5} - f_{q5})^2 + (f_{p6} - f_{q6})^2} \quad (3)$$

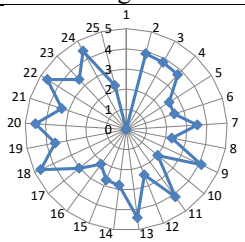
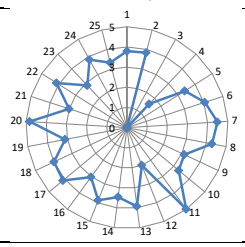
where *Xp, Xq* – clothing models with conditional numbers *p*, *q*;
$f_{p1}, f_{p2}, f_{p3}, f_{p4}, f_{p5}, f_{p6}$ ($f_{q1}, f_{q2}, f_{q3}, f_{q4}, f_{q5}, f_{q6}$) – set values of key design attributes of clothing models with conditional digits *p* (*q*), respectively.

Thus, according to the results of factor analysis, 6 factors (components) have been identified, in which all pairs of design attributes that reflect the consumer's impression from clothing can be combined, were f_1 –composition feature of clothes style; f_2 – characteristics of clothes colour; f_3 – style characteristics by the situation of use and functionality; f_4 – characteristics of clothes texture; f_5 – clothes colours; f_6 –geometric symbols of clothes shapes [11-13].

Visualization of differences in clothing models belonging to different clusters is presented in the form of spider diagrams. The analysis of the diagrams indicates the adequacy of the performed cluster analysis, as all cluster centers differ from each other. As a result of the cluster analysis 25 conventional groups were selected [10]. In each cluster there are models of different colours that are in separate cells. This approach allows to detail the search for the desired models in a common database of images, the results are presented in table 1.

Table 1

Belonging of clothes' models to clusters (Cl) (fragment)

Cluster	Colour	Model number	Photo from database	Diagram
1	Red	1		
3	Black	51, 57		

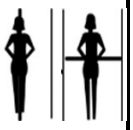
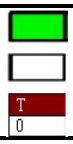
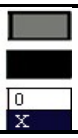
According to the results of factorial and cluster analysis we may form a productive ES models for choosing

clothes considering the wishes (opinions) of a consumer. ES model of production presupposes knowledge of the relationship between the concepts. The relationship between the concepts is presented in the form of ordered sequences $Cl_i=(f_{1i}, f_{2i}, f_{3i}, f_{4i}, f_{5i}, f_{6i})$ and $M = (Cl_i, colour)$, where i is a model number.

The ES illustrated in this paper is based on the expert rules. It can help customers selecting the most suitable clothes among the abundant apparel according to personal condition and increase customers' satisfaction. The structure of apparel recommended ES is shown in table 2.

Table 2

The structure of the expert system «Clothing model selection» (fragment)

Entity	The answer number	Scale SD	Meaning	Comment	Figure
1	*2*	*3*	*4*	*5*	*6*
Evaluate the level of symmetry of the model of clothing that is under design, 1 - symmetry, 7 is not symmetric at all	1	-3	Vertical or horizontal symmetry	Garment consists of relatively equal parts. It displays an idea of the traditional forms of various types of clothing. It is associated with such words as follows: static, proportional, balanced, respectable, rigorous, and elegant.	
	2	-2	…	…	…
	3	-1	…	…	…
	4	0	…	…	…
	5	+1	…	…	…
	6	+2	…	…	…
	7	+3	Vertical or horizontal asymmetry	It is common for the avant-garde style. It strikes with its unusual appearance and reveals the fashion trends ahead of time. Garment that consists of no equal parts. It is associated with such words as follows: expressive, dynamic, exclusive, charming, creative, extravagant.	
Choose the characteristics of the required/fashionable colour palette	1	-3	Bright light warm colour	S=0÷50%, B=59÷100%, H=0÷75° It is associated with such words as follows: festive, refreshing, dynamic, easy, transparent, soft, dazzling, fun, cheerful.	
	…	…	…	…	…
	7	+3	Soft dark cold colour	S=0÷100%, B=0÷13%, H=220÷290° It is associated with such words as follows: deep, matte, intellectual, heavy, classical, conservative, chic, official, reserved.	

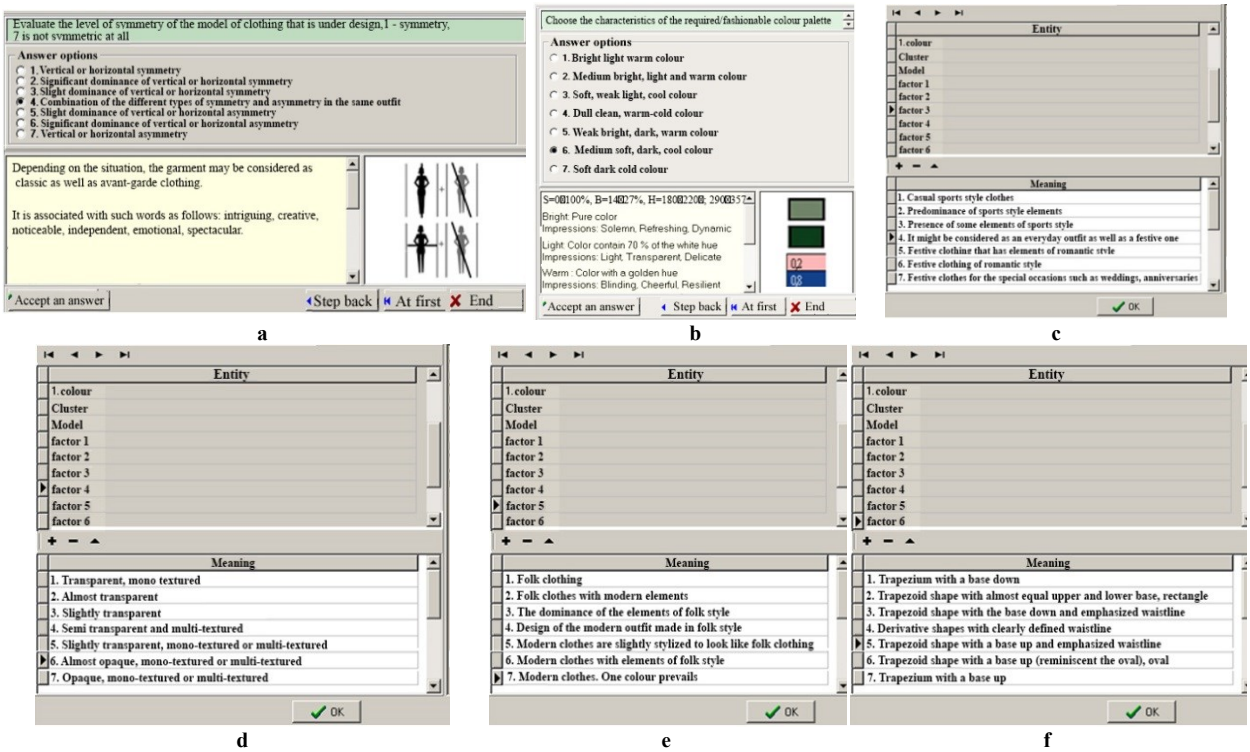


Fig. 1. Dialogues of ES prototype of subtask of readymade garments' selection based on the methodology of KE: a) - the choice of the symmetry model of designed clothing; b) - choice of outfit's colour characteristics; c) - the choice of factor 3; d) - the choice of factor 4; e) - the choice of factor 5; f) the choice of factor 6

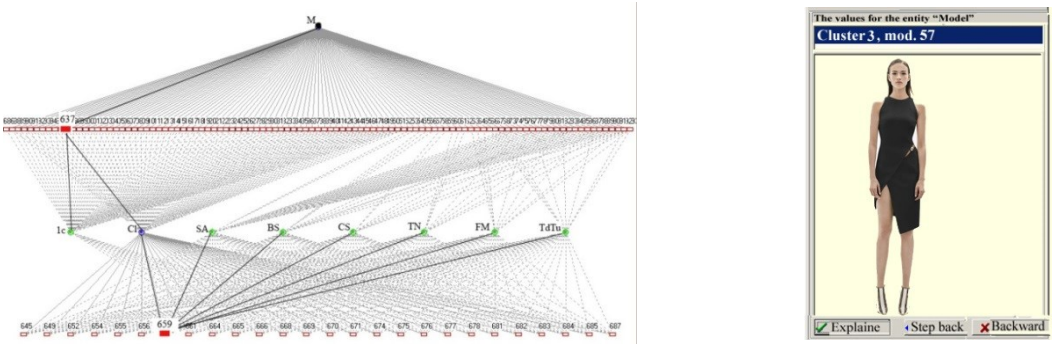
Prototype of ES of a subtask of models' selection based on the methodology of KE in the shell «Rapana» provides a dialogue with the user as a series of questions and answers of system's user.

Experimental

The object of the study is the women's fashion dresses in spring-summer 2023 season. Thus, a general collection was formed which amounted to 66 photos of fashion dresses for subsequent questionnaire [14].

As a result of the dialogue of the address consumer with the ES 57 model of women's dresses was selected from the formed base of 66 images. Examples of dialogues of the ES are shown in Fig. 1-3 [11].

Decision making (Fig. 2, 3) provides for the implementation of rules 637 and 659, which are involved in entities: *M* – model, *1c* – colour, *Cl* – cluster, *SA* – symmetry-asymmetry clothes, *BS* – colour characteristics, *CS* – casual, elegant clothes, *TN* – tissue characteristics, *FM* – folk, modern clothes, *TdTu* – dress. The way how the decision is made is marked with a thick line.



a **b**

Fig. 2. The result of the dialogue: a) - the way of the decision-making; b) - the proposed clothes' model

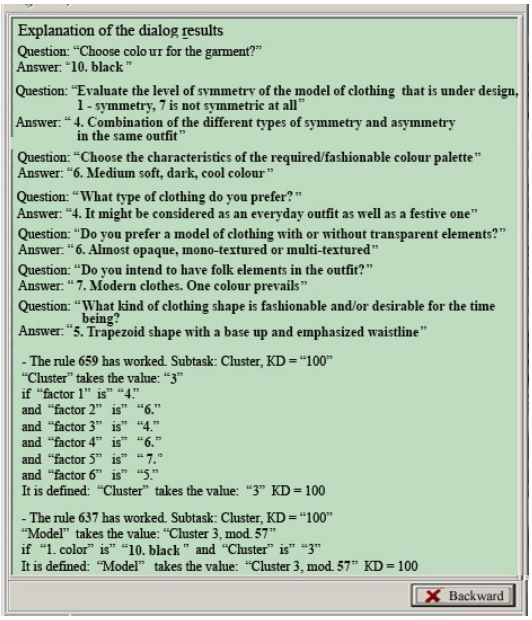


Fig. 3. Explanation of the dialogue result

Table 3

Results of the evaluation degree of coordination of expert opinions

№ Photo	Code	Professionals (10 experts)										Kf	Consumers (16 experts)																Kc	K
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*		*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*		
57	*CS*	1	0	1	3	3	1	2	2	2	3	1,80	1	3	3	2	2	1	2	2	2	2	3	1	1	2	2	2	1,94	1,87
	RS	1	1	0	1	1	2	0	0	1	3	1,00	1	1	0	1	0	1	1	1	2	0	0	1	1	2	1	1	0,88	0,94
	CA	2	3	3	3	3	3	3	3	3	3	2,90	2	3	3	3	3	3	3	3	2	3	3	3	2	3	3	3	2,81	2,86
	FM	3	3	3	3	3	3	3	3	3	3	3,00	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3,00	3,00
	RO	0	2	2	0	3	1	3	1	0	3	1,50	0	2	2	1	3	1	3	2	2	1	3	0	0	2	2	2	1,63	1,56
	TdTu	0	0	0	0	0	0	0	0	0	0	0,00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,00	0,00
	MP	2	2	1	1	1	1	1	1	1	1	1,20	2	2	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1,25	1,23
	BS	-3	-3	-2	-2	-3	-3	-3	-2	-2	-3	-2,60	-3	-3	-2	-3	-3	-2	-3	-3	-3	-2	-3	-3	-2	-2	-3	-3	-2,69	-2,64
	LD	-1	-3	-3	-3	-3	-3	-3	0	-2	0	-2,10	-1	-3	-2	-1	0	-1	-3	-3	-2	-3	-3	-2	-3	-2	-3	-2	-2,13	-2,11
	WC	2	3	3	2	3	2	3	3	2	3	2,60	3	3	2	3	2	3	2	3	3	2	3	3	2	3	2	3	2,63	2,61
	MtPt	3	1	2	1	1	1	3	1	2	1	1,60	3	3	2	1	1	1	3	1	2	2	1	3	1	1	1	1	1,69	1,64
	MS	-2	-3	-3	-2	-3	-3	-3	-3	-3	-3	-2,80	-2	-3	-3	-3	-3	-2	-2	-3	-3	-2	-3	-3	-2	-2	-3	-3	-2,25	-2,53
	TN	3	3	3	3	3	3	3	3	3	3	3,00	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3,00	3,00
	SA	3	3	3	3	3	3	3	3	3	3	3,00	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3,00	3,00

Results

Photos of outfits, which are shown in the figure 2 b, were assessed by experts using the questionnaire, which was developed and submitted in [11].

The expert group consisted of 10 experts and 16 consumers. In a survey photos of clothes were valued using evaluation factors in bipolar scales defined by verbal antonyms of KW from each end of the scale (table 3).

The consistency degree of photo evaluation results by experts using SD scales is confirmed by concordance coefficients and Pearson criteria. Table 4 presents the consolidated results of the evaluation level coordination of expert opinions of the first five models.

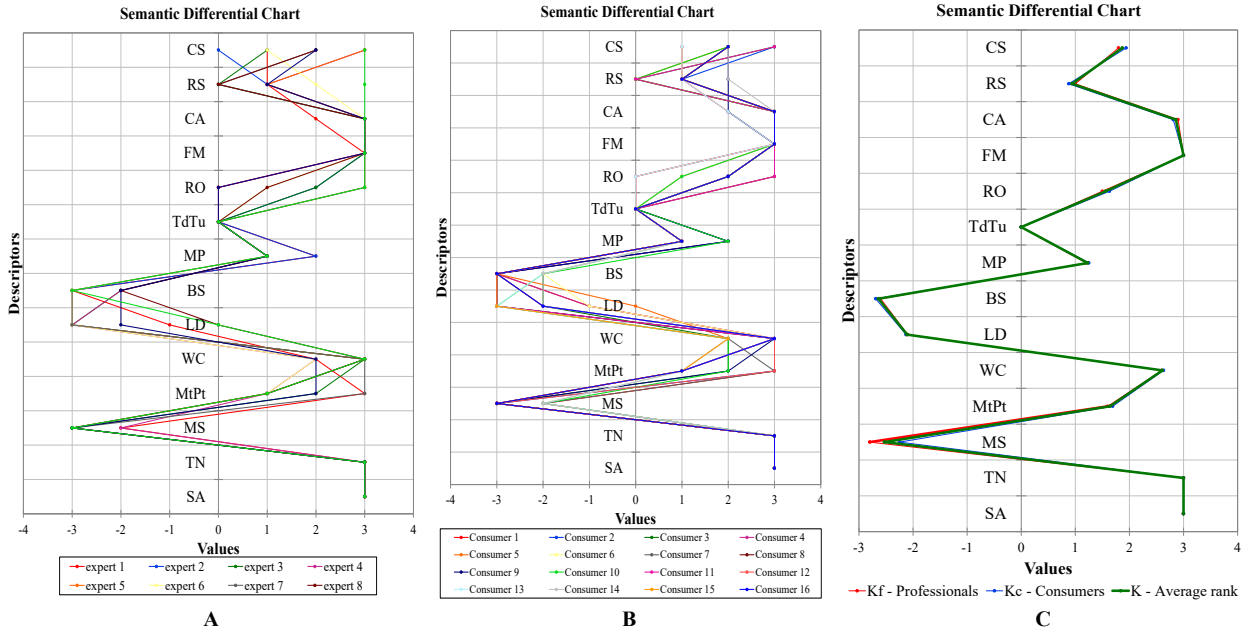
Table 4

The consolidated results of the evaluation degree of coordination of expert opinions (fragment)

Number of an outfit	ω for the expert group		χ^2_p for the expert group	
	professionals (10 people)	*consumers (16 people)*	*professionals*	*consumers*
57	0.734	0.898	95.42	186.74

Therefore, it is possible to state with 95-percent probability that the frequency of evaluation ratios of KW pairs in different experts is coordinated in accordance with the calculated rate of concordance.

Since these evaluations are subjective, as a result of the survey psychographic profile of the dress 57 was constructed (Fig. 4). Each profile is a list of the average meanings of the estimated coefficients of semantic differential from table 3.



A **B** **C**

Fig. 4. Examples of psychographic profiles: a) - experts are professionals; b) - experts are consumers; c) - total results

As shown in Fig. 4 psychographic profile of an outfit visually practically does not differ for different groups of experts. As a result, clothes' models that have roughly the same psychographic profiles present each of the 25 received clusters. Combinations of characteristics, which define each of clusters, are to be used in forming the productive model of ES under development.

Conclusion

This research is devoted to implementation of the expert systems for rapid change in production of women's outerwear. Factorial analysis and the cluster analysis are used for the structuring of the subject environment. Thus, the main objective of the study was achieved through the formation of rules of decision-making that intent to solve subtasks of rapid change in production of women's outerwear and choosing the models of readymade garments based on Kansei Engineering methodology. In addition, the system can be used for the designing and for the selection of readymade garments that meets pre-defined customer's impressions (eg. in the shops, including online stores) and to select a prototype to develop new model of clothing that meets the wishes of the consumer.

The knowledge base has been developed in the empty shell «Rapana». It provides dialogue as a series of questions by the system and answers by the user. User can view the way decision making after getting results.

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