An Intelligent Recommender System for Personalized Fashion Design

X. Zeng and L. Koehl
GEMTEX Laboratory, ENSAIT
2 allée Louise et Victor Champier 59056 Roubaix France
University of Lille Nord de France
xianyi.zeng@ensait.fr

L. Wang and Y. Chen
National Engineering Laboratory for Modern Silk
College of Textile and Clothing Engineering
Soochow Universit
215021 Suzhou, P.R.China

Abstract **– This paper originally proposes an intelligent recommender system for supporting personalized fashion design. Based on two models characterizing relations between human body measurements and human perceptions on human body shapes, we develop the criteria permitting to evaluate a set of new design styles for a specific garment customer and a desired fashion theme. In this approach, the intelligent techniques, including decision trees, cognitive maps and fuzzy relations computation, have been used.**

I. INTRODUCTION

A recommender system is an information filtering system that seek to predict the 'rating' or 'preference' or 'relevancy' that a user would give to an item or social element they had not yet considered, using a model built from the characteristic of an item or the user's social environment [1, 2].

Recently, recommender systems have been massively applied in e-shopping in order to suggest similar or related personalized products for a given customer. These systems are mainly classified into three categories [3]: 1) Content-based filtering approach, aiming at discovering product attributes and relations between products and between customers; 2) Collaborative filtering approach, aiming at exploiting information about user interaction and transactions such as product ratings and orders; and 3) Hybrid approach, which combines the two previous approaches. Recommender systems have been largely developed in different economic sectors, such as e-shopping, web searching, education and tourism.

Recommender systems have also attracted much attention in fashion industry for realizing personalized garment design, including personalized fashion styles and colors and optimized fit between body shapes and garments. Both fashion designers and garment consumers can benefit from these systems for identifying a new product the most relevant to his/her personalized requirements in fashion and comfort. A recommender system supporting online garment selection based on the customer's tastes was proposed by Sekozawa using AHP (Analytical Hierarchy Process) [4]. A fuzzy screening-based fashion coordination system was proposed by Wong et al. for providing customers with professional and systematic mix-and-match recommendations and simulating the decisions of fashion designers [5]. A hybrid recommender system for fashion style advice was proposed by Vogiatzis et al. [6]. It is based on the domain expertise, expressed through a fashion ontology, for generating a genetic recommendation relevant to the body type, facial features and occasions, and then user interaction data with fashion sites, for computing the similarity of genetic garments with real ones and delivering recommendations about real garments. Also, an intelligent fashion design system was developed by integrating a cognitive model, namely Multi-alternative Decision Field Theory (MDFT), with a Genetic Algorithm to model the personalized style preferences, and trying to account for the contextual effects occurred in multi-alternative decision making and get a relatively quick prediction of the costumer's fashion style decision in the mean time [7].

The existing fashion recommender systems mainly focus on the relations between products and consumers and rarely deal with human perception and emotion on fashion products. In practice, the consumer's perception and emotion play a very important role in the final decision of fashion product purchasing. Beyond the simple appreciations such as preferences and ratings, human perception on fashion products is a complex concept and can be generally into two categories: 1) basic sensory criteria neutrally describing the general perception on the product without taking account its socio-cultural context, 2) fashion themes or ambiances describing how the fashion product is used and visualized in different social scenarios [8]. For a fashion product, the emotion expressed through fashion themes constitutes its significant added value. For a specific costumer, a suitable fashion recommender system should recommend garments and accessories adapted to his/her body shape at the levels of both basic perception and desired emotional fashion theme. Moreover, it should integrate the knowledge and experience of trained fashion professionals in order to select appropriate fashion design schemes (material, styles and colours).

In this paper, we propose a perception-based recommender system for supporting fashion designers to select the best personalized fashion design scheme. In this system, the techniques of sensory evaluation are used to extract human perception data from design experts on the basic sensory attributes of human body shapes. In the same time, consumer's perception on relations between the basic sensory attributes of body shapes and the concerned fashion theme are also evaluated. These consumer's data are strongly related to a socio-cultural context. A fashion theme such as "sporty" and "professional" can be considered as a social image desired by the consumer and orientation of new design. During the design process, designers should make efforts to

978-1-4799-0348-1/13/$31.00 ©2013 IEEE

reduce the gap between the naked body shape of the consumer and the desired fashion theme by proposing to him/her new appropriate personalized garments.

In the proposed recommender system, the techniques of artificial intelligence, especially fuzzy logic, constitute the main computational tools for formalization and modelling of perceptual data. The perceptual data of both consumers and designers are formalized mathematically using fuzzy sets and fuzzy relations. Moreover, the complex relation between human body measurements and basic sensory attributes, provided by designers, is modelled using fuzzy decision trees. And the complex relation between basic sensory attributes and fashion themes, given by consumers, is modelled using fuzzy cognitive maps. The former is an empirical model based on learning data measured and evaluated on a set of representative samples. The latter is a conceptual model obtained from cognition of consumers. The combination of the two previous models can provide more complete information to the fashion recommender system, permitting to evaluate a specific body shape related to a desired fashion theme and obtain the design orientation in order to improve the image of the body shape.

II. Perception, Evaluation and Formalization

The proposed recommender system aims at designing men's overcoats. For this purpose, three sensory experiments are carried out for collecting human perception data. *Experiments I* and *II* aim at extracting from their perceptions, fashion designer's knowledge and experience about body shapes and relations between body shapes and design styles. *Experiment III* enables to identify consumer's cognition on fashion themes and their relations with body shapes.

A. Experiment I: Sensory Evaluation of Naked Male Body Shapes

In this experiment, the fashion expert's perception on human body shapes is extracted through sensory evaluations on a set of basic and concrete sensory descriptors describing the basic nature of naked male body shapes. A classical normalized sensory evaluation procedure is adopted to perform this task [9].

First, twelve various virtual male body types are generated by using the software MODARIS 3D Fit, for covering the entire population of the South-East Region in China.

From each of these virtual naked body shapes, the fashion experts select six key body measurements, considered as the most relevant to the aesthetic effect of men's entire and upper body. These measurements include

Stature, total length of arm, chest circumstance, neck circumstance, waist circumstance and hip circumstance

During the sensory evaluation procedure, the trained fashion experts describe the features of these body shapes using a set of normalized descriptors, selected from different references [10]. All the evaluators use the same descriptors during their evaluations and receive a training session in order to understand the meaning of these descriptors. The method of semantic differential scale is used for expressing these descriptors. Finally, we obtain 22 normalized pairs of descriptors as follows.

Thin – fat, slim – bulgy, dented – swollen, atrophic – forceful, short – tall, narrow – wide, flat – thick, non-streamline – streamline, knotty – smooth, shrive – fleshly, effeminate – lusty, fragility – strong, inelastic – elastic, deft – awkward, cabinet – huge, unbalanced – harmonious, unique – normal, unstylish – stylish, sebaceous – muscular, lazy – vivid, light – heavy, unsexy – sexy

Fig. 1 Comparison of two virtual body types: *CA170* and *CC155*.

The evaluation is performed by comparing each virtual body shape with a standard one denoted as *CA170* for each sensory descriptor. One example is shown in Fig. 1. For each expert and each descriptor, the evaluation or comparison result takes a value from the set {C_1 *(very inferior)*, C_2 *(inferior)*, C_3 *(fairly inferior)*, C_4 *(a little inferior)*, C_5 *(identical)*, C_6 *(a little superior)*, C_7 *(fairly superior)* C_8 *(superior)*, C_9 *(very superior)*}.

B. Experiment II: Sensory Evaluation of Male Body Shapes with Design Style

In this experiment, the objective is to extract the fashion expert's experience about how fashion style change the perception of a human body shape. Five classical styles of male overcoats, including "*Chester*", "*Ulster*", "*Balmacaan*", "*Trench*", and "*Duffle*", are selected as garment references.

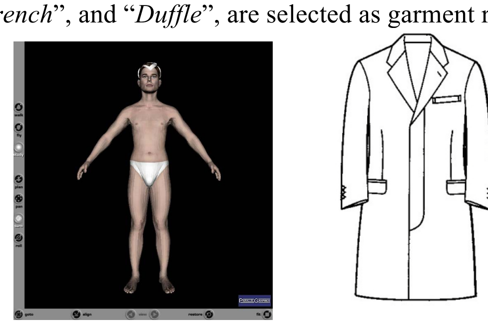


Fig. 2 Comparison of the body shape *CA170* and the garment style *Chester*.

In this experiment, the same fashion experts involved in Experiment I are invited to perform evaluations with garment styles. Different from *Experiment I* which compares a number of specific naked body shapes shape with a standard one, we invite the evaluators to compare the naked standard body shape *CA170* with each reference style for the same sensory descriptors defined in *Experiment I*. This treatment is due to the fact that designers of the mass market usually create styles on a standard mannequin. One example is shown in Fig. 2. For each descriptor, each fashion expert also gives a evaluation score from the set $\{C_1, C_2, ..., C_9\}$. Compared with *Experiment I,* the fashion experts need to apply more their professional knowledge and experience during the evaluation.

C. Experiment III: Cognition of Fashion Themes and Their Relations with Body Shape Perceptions

Three fashion themes, namely "sporty", "nature" and "attractive", are considered in this experiment. For each theme, a number of representative images are presented to the consumer evaluators so that they understand better the related ambiance. During the evaluation, each evaluator is asked to give a linguistic evaluation score for characterizing the relevancy degree of each sensory descriptor describing body shapes, to each fashion theme. These evaluation scores take values from the set $\{R_1$ *(very irrelevant)*, R_2 *(fairly irrelevant)*, R_3 *(neutral)*, R_4 *(fairly relevant)*, R_5 *(very relevant)*$\}$.

D. Formalization of the Fashion Recommender System

The previous concepts are formalized as follows.

Let $T=\{t_1, t_2, ..., t_n\}$ be a set of n fashion themes characterizing the socio-cultural categories of body shapes. We have $n=3$ in Experiment III.

Let $D=\{d_1, d_2, ..., d_m\}$ be a set of m basic sensory descriptors extracted by the fashion experts for describing various body shapes. In Experiments I and II, we have $m=22$.

Let $W=\{w_1, w_2, ..., w_p\}$ be a set of p virtual body shapes generated from the software MODARIS 3D FIT.

Let $BM=\{bm_1, bm_2, ...bm_h\}$ be a set of h body measurement features characterizing body shapes.

Let $BR=\{br1, br2, ..., brg\}$ be a set of g body ratio indexes calculated from the body measurement features in BM. For fashion experts, BR is more relevant than BM for quantitatively characterizing body shapes. The body ratios of all the p virtual body shapes in W constitute a matrix, denoted as $(br_{ij})_{g\times p}$ with $i=1, ..., g$ and $j=1, ..., p$.

Let $EX=\{ex_1, ex_2, ...ex_r\}$ be a set of r fashion experts evaluating the relevancy of the sensory descriptors in D to naked body shapes in W by comparing them with *CA170*.

Let $EC=\{ec_1, ec_2, ...ec_z\}$ be a set of z consumers evaluating the relevancy of the sensory descriptors in D to the fashion themes in T.

Let $S=\{s_1, s_2, ...s_\xi\}$ be a set of ξ reference garment styles used in the design process.

Let $DE=\{de_1, de_2, ...de_\lambda\}$ be a set of λ new garment styles generated for a specific body shape. These new styles are generated by making combinations of the reference styles.

III. Structure of the Proposed Recommender System

The structure of the proposed fashion recommender system is described in Fig. 3. It is composed of three functional blocks: *Inputs*, *Learning data* and *Decision support unit*. The perceptual data of fashion experts and consumers, obtained from the previous sensory experiments, will be taken as learning data of the *Decision support unit*. The *Decision support unit* will determine, through a series of computations, whether a specify body shape is conform to a given fashion theme. *Inputs* is an user interface permitting the designer to input three parameters, namely a specific body shape, represented by its body ratios BR^Y, the desired fashion theme t_i, and a newly designed garment style de_v, obtained by combining different reference styles.

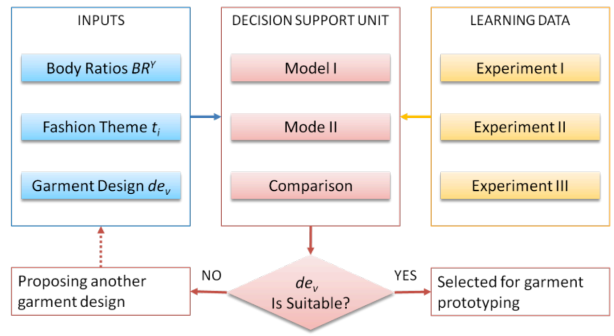


Fig. 3 The proposed fashion recommender system.

The first stage of the *Decision support unit* is *Model I*, whose aim is to evaluate the relevancy of a specific naked body shape *Y*, expressed by its body ratios BR^Y, related to a desired fashion theme t_i. The second stage of this unit is *Model II*, whose aim is to evaluate the relevancy of a specific body *Y* with a garment style de_v related to t_i. In the last stage of this unit, the previous two relevancy results are compared by using a gravity centre-based criterion in order to evaluate whether the newly designed style de_v is suitable for the body shape *Y* in terms of image improvement towards the fashion theme t_i.

A. Model I

Model I is used to predict three relevancy degrees, namely the relevancy degree of the naked body ratios BR^Y to the sensory descriptors in *D*, denoted as $REL(D, BR^Y)$, the relevancy degree of the sensory descriptors in D to a given fashion theme t_i, denoted as $REL(t_i, D)$, and the relevancy degree of the naked body ratios BR^Y to the fashion theme t_i, denoted as $REL(t_i, BR^Y)$. The functional structure of *Model I* is described in Fig. 4.

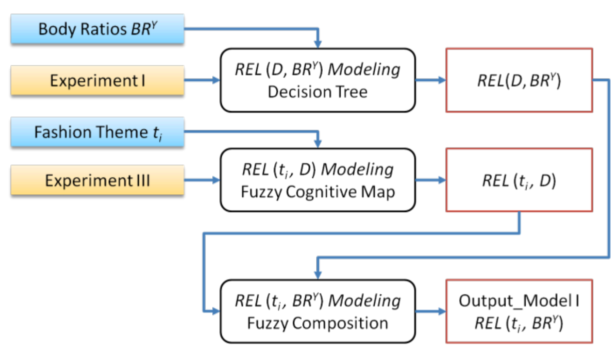


Fig. 4 The functional structure of *Model I*.

$REL(D, BR^Y)$ characterizes the relation between *D* and BR^Y. It is modelled using a number of fuzzy decision trees by learning from the perceptual data obtained from *Experiment I*. Fuzzy decision trees are more efficient for treating learning data of mixed type, including both numerical and categorical data [11]. Furthermore, fuzzy decision trees can represent classification knowledge more naturally to the way of human thinking. They are more robust in tolerating imprecise, conflict, and missing information for treat the problems of cognitive uncertainties. In our approach, the Fuzzy ID-3 algorithm is used to build the fuzzy trees. For any specific body ratios BR^Y, we obtain from this model a relevancy degree for each sensory descriptor in D.

$REL(t_i, D)$ characterizes the relation between t_i and D. It is modelled using a fuzzy cognitive map, built from the consumer perceptions extracted from *Experiment III*. Fuzzy cognitive map is an efficient tool for representing human knowledge and cognitions on relations between abstract fashion themes and specific body shapes. It offers a good approach to the stimulation and aggregation of human perceptions provided by multiple evaluators [12].

The two previous models are then combined using a fuzzy relation composition for computing the general relevancy degree of a specific body shape to a given fashion theme. More details can be found in [13].

B. *Model II*

Model II is used to predict two fuzzy relations, namely the relevancy degree of a number of reference styles in S to a newly designed garment style de_v, denoted as $REL(de_v, S)$, the relevancy degree of the standard body shape *CA170* with a reference style s_λ in S to the sensory descriptors in D, denoted as $REL(D, s_\lambda)$. These two relevancy degrees are calculated from the sensory data of *Experiment II*.

By successively combining the two previous fuzzy relations and $REL(t_i, D)$, calculated from *Model I*, we obtain the relevancy degree of the standard body shape *CA170* with the newly designed style de_v to the desired fashion theme t_i, denoted as $REL(t_i, BR^{CA170} \vee de_v)$. Next, by applying the union operation between $REL(t_i, BR^{CA170} \vee de_v)$ and $REL(t_i, BR^Y)$, we obtain the relevancy of any body shape Y with a newly designed style de_v to the designed fashion t_i, denoted as $REL(t_i, BR^Y \vee de_v)$. The functional structure of Model II is described in Fig. 5.

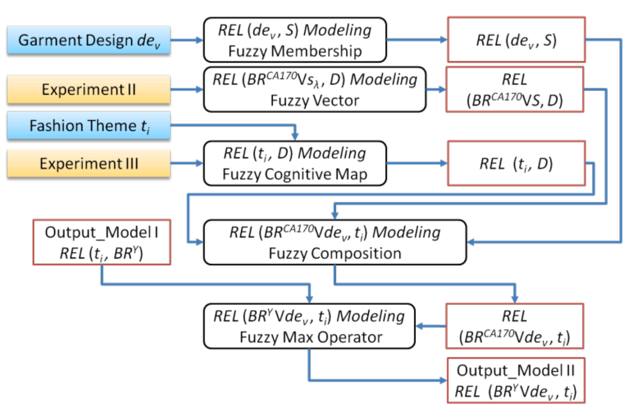


Fig. 5 The functional structure of *Model II*.

C. *Comparison of the Two Relevancy Degrees*

For a given body shape Y, we compare its naked relevancy degree and that with the design style de_v to the fashion theme t_i in order to determine if this new style really improves its image towards the direction of t_i. The style de_v is considered as a feasible design style if this improvement can be validated by the comparison of these two relevancy degrees.

In our approach, the gravity centers of fuzzy relations or fuzzy matrices are used to determine the comparison criteria. For computing the gravity center of $REL(t_i, BR^Y)$, we first transform the linguistic evaluation values $\{R_1, R_2, R_3, R_4, R_5\}$ into their equivalence numerical values $\{0, 0.25, 0.5, 0.75, 1\}$, and $\{C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8, C_9\}$ into $\{-1, -0.75, -0.5, -0.25, 0, 0.25, 0.5, 0.75, 1\}$.

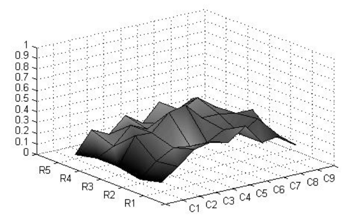
The gravity center of the fuzzy relation matrix

$$REL(t_i, BR^Y) = \begin{pmatrix} \mu_i^Y(R_1, C_1) & \dots & \mu_i^Y(R_1, C_9) \\ \vdots & \ddots & \vdots \\ \mu_i^Y(R_5, C_1) & \cdots & \mu_i^Y(R_5, C_9) \end{pmatrix}$$

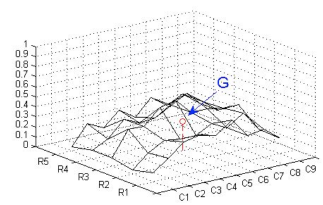
is calculated by

$$G_{REL(t_i, BR^Y)} = \sum_{j=1}^{5}\sum_{k=1}^{9} \mu_{jk}\, eq(R_j)\, eq(C_k)$$

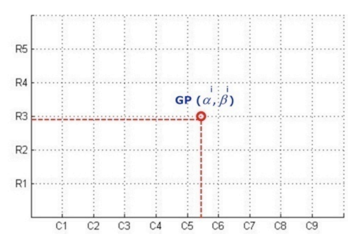
where $eq(R_j)$ and $eq(C_k)$ are the equivalence values of R_j and C_k respectively.



(a) Distribution of a fuzzy relation matrix



(b) Gravity center of the distribution



(c) Projection of the gravity center on the ($Y \times t_i$) plan

Fig. 6 Fuzzy relation, its gravity centre and its projection.

The projection of the gravity centre on the axis Y is calculated by

$$\alpha^i = G_{REL(t_i, BR^Y)} / \sum_{j=1}^{5}\sum_{k=1}^{9} \mu_{jk}\, eq(R_j)$$

Similarly, the projection of the gravity centre on the axis t_i is calculated by

$$\beta^i = G_{REL(t_i, BR^Y)} / \sum_{j=1}^{5}\sum_{k=1}^{9} \mu_{jk}\, eq(C_k)$$

The combination of these two projections is

$$GP^{Y\times t_i}_{REL(t_i,BR^Y)} = (\alpha^i, \beta^i)$$

The product of the above two projection s defined by

$\omega^i = \alpha^i \cdot \beta^i$

For the fuzzy matrix $REL(t_i, BR^Y \vee de_v)$, its gravity centre and projections, denoted as $\overline{\overline{\alpha^i_v}}$ and $\overline{\overline{\beta^i_v}}$, are calculated in the same way. The product of these two projections is denoted as $\overline{\overline{\omega^i_v}}$.

The image difference between the naked body shape Y and Y with the newly designed garment style de_v related to the fashion theme t_i, can be characterized by calculating the corresponding projections, namely

$\Delta\alpha^i_v = \overline{\overline{\alpha^i_v}} - \alpha^i$ $\qquad$ $\Delta\beta^i_v = \overline{\overline{\beta^i_v}} - \beta^i$

And the corresponding difference of the projection products is $\Delta\omega^i_v = \overline{\overline{\omega^i_v}} - \omega^i$

For comparing the relevancy degrees obtained from *Model I* (for the naked body shape) and *Model II* (for the body shape with a new garment style), we define the following rules:

Rule 1: For the value of α (α^i or $\overline{\overline{\alpha^i_v}}$):

Bigger is α, higher is the relevancy degree of the body shape Y (naked or with garment design style) to the fashion theme t_i for design expert perception. Otherwise, the relevancy degree is lower.

Rule 2: For the value of β (β^i or $\overline{\overline{\beta^i_v}}$):

Bigger is β, higher is the relevancy degree of the body shape Y (naked or with garment design style) to the fashion theme t_i for consumer perception. Otherwise, the relevancy degree is lower.

Rule 3: For the value of ω (ω^i or $\overline{\overline{\omega^i_v}}$):

Bigger is ω, higher is the relevancy degree of the body shape Y (naked or with garment design) to the fashion theme t_i for the compromise between design expert perception and consumer perception. Otherwise, the relevancy degree is lower.

Therefore, if $\Delta\omega^i_v$ is a positive value, the relevancy degree of the body shape Y with the garment design de_v to the fashion theme t_i is higher than that of the naked body shape Y for the compromise between the expert perception and the consumer perception.

If $\Delta\omega^i_v$ is 0, there is no difference.

If $\Delta\omega^i_v$ is a negative value, the relevancy degree of the body shape Y with the garment design de_v to the fashion theme t_i is smaller than that of the naked body shape Y for the compromise between the expert perception and the consumer perception.

According to the previous rules of comparison and analysis, we define the evaluation criterion of new garment design styles as follows:

If the value of $\Delta\omega^i_v$ is positive, the garment design style de_v should be selected as a feasible design style for improving the relevancy of the body shape Y to the fashion theme t_i. Otherwise, the design style de_v should be rejected.

IV. Two Design Applications

The proposed fashion recommender system is applied to two real design scenarios for validating its effectiveness. The first scenario is the customized design while the second is the mass market selection.

A. Scenario 1: Customized Design

Three consumers with different body shapes, denoted as *Y01*, *Y02* and *Y03* are selected for customized design. Six body measurements are taken for each body shape ($h=6$) and the corresponding data are shown in Table 1.

Body measurements (cm)	*Y01*	*Y02*	*Y03*
bm_1 *(stature)*	*169*	*171.5*	*162.5*
bm_2 *(arm length)*	*53.5*	*54.5*	*49*
bm_3 *(chest circumstance)*	*89.5*	*80*	*84.6*
bm_4 *(neck circumstance)*	*37*	*36*	*36.5*
bm_5 *(waist circumstance)*	*76.5*	*65*	*68.8*
bm_6 *(hip circumstance)*	*94*	*87*	*86.1*

Table 1 Body measurements of the three body shapes.

The aim of the customized design is to propose new styles for male overcoats towards the fashion theme "*Attractive*". By combining the design elements of the five reference styles, described in *Experiment II* of Section II, the designer proposes three new styles shown in Fig. 7.

de_1 $\qquad$ de_2 $\qquad$ de_3

Fig. 7 Three newly designed styles for customized overcoats

As each newly designed style can be characterized by the membership degrees of the five reference styles, we have

de_1: totally belonging to "*Chester*"

de_2: totally belonging to "*Duffle*"

de_3: fairly belonging to "*Chester*" and a little to "*Ulster*"

Next, for each specific customer, by calculating the relevancy degree of the naked body and those with three new styles, we obtain the corresponding values of $\Delta\omega^i_v$, shown in Table 2.

	de$_1$		de$_2$		de$_3$	
	$\Delta\omega^i_v$	feasible?	$\Delta\omega^i_v$	feasible?	$\Delta\omega^i_v$	feasible?
Y01	0.52	Yes	-0.28	No	0.15	Yes
Y02	2.60	Yes	0.34	Yes	1.85	Yes
Y03	0.74	Yes	-0.39	No	-0.09	No

Table 2 Evaluation of the three new styles for three different customers.

From Table 2, we can find that $de_1$and de_3 are feasible for *Y01*. For *Y02*, all the three styles are feasible. For *Y01*, only de_1 is feasible. The style de_1 can be considered as the best general recommendation for all the customers. The style de_3 can be considered as a special recommendation only adapted to the body shape *Y02*.

B. Scenario 2: Mass Market Selection

The aim of this design is to select a set of feasible design styles meeting the needs of one population instead of one personalized body shape. In this context, we select 60 male customers with different body shapes. The objectives of this design can generally several fashion themes. In our study, we propose three objectives, namely

Objective 1: "*Sporty*" and "*Nature*"

Objective 2: "*Sporty*" and "*Attractive*"

Objective 3: "*Nature*" and "*Attractive*"

Six new styles are described using their linguistic membership degrees related to the five reference styles, namely

de_1: totally belonging to "*Chester*"

de_2: totally belonging to "*Duffle*"

de_3: fairly belonging to "*Chester*" and a little to "*Ulster*"

de_4: a little belonging to "*Chester*" and fairly to "*Ulster*"

de_5: fairly belonging to "*Balmacaan*" and a little to "*Trench*"

de_6: a little belonging to "*Balmacaan*" and totally to "*Trench*"

Table 3 gives the rates of feasible responses of all the 60 body shapes for each new design style and each objective. As each objective is composed of two fashion themes, a response is feasible if and only if the evaluation criteria $\Delta\omega_v^i$ are positive for both fashion themes. In any case, higher is the evaluation criterion, more feasible the corresponding design style is to the design objective.

	de_1	de_2	de_3	de_4	de_5	de_6
Objective 1	*53%*	*17%*	*53%*	*43%*	*40%*	*65%*
Objective 2	*68%*	*17%*	*63%*	*43%*	*32%*	*60%*
Objective 3	*53%*	*22%*	*53%*	*55%*	*32%*	*58%*

Table 3 Statistical results of feasible responses for all the body shapes.

In our study, we define the following rules for selecting relevant design styles for the whole population:

Rule 1: If the rate of feasible responses ≥50%, the corresponding style will be selected for the population.

Rule 2: The design style having the highest rate of feasible responses will be regarded as the best solution.

	Feasible selection	***Best selection***
Objective 1	de_1, de_3, de_6	de_6
Objective 2	de_1, de_3, de_6	de_1
Objective 3	de_1, de_3, de_4, de_6	de_6

Table 4 Recommendation results for the whole population.

According to these rules, the final recommendations for three different design objectives are shown in Table 4.

V. CONCLUSION

In this paper, we propose an original perception-based fashion recommender system for supporting fashion designer's creations. Different from the existing recommender systems, which mainly focus on relations between products and between customers, the proposed system permits to take into account complex perceptions of both design experts and general costumers, including their knowledge, experience and personal preferences. This system is especially significant for recommending fashion related products and human-centered products.

Intelligent techniques, including fuzzy decision trees, fuzzy cognitive maps and fuzzy relation operations, have been used in this system for dealing with uncertainty related to human perceptions.

In practice, the proposed recommender system can be applied to both personalized or customized product design and mass market-oriented design.

The proposed recommender system can be further extended to other application scenarios beyond fashion design for predicting how suitable an item is for a specific user in a given context. The extended system can be considered as a task of "recommend top-k most suitable items".

REFERENCES

[1] F. Ricci, L. Rokach and B. Shapira, "Introduction to recommender systems handbook," in *Recommender Systems Handbook*, Eds. F. Ricci et al. Springer US, pp. 1-35, 2011.

[2] L. Martinez, L.G. Pérez, M.J. Barranco and M. Espinila, "A knowledge based recommender system based on consistent preference relations" *Intelligent Decision and Policy Making Support Systems*, Eds. D. Ruan et al. Springer, pp. 93-111, 2008.

[3] G. Adomavicius and A. Tuzhilin, "Towards the next generation of recommender systems: a survey of the state-of-art and possible extentions" *IEEE Transactions on Knowledge and Data Engineering*, vol. 17, n°6, pp. 734-749, 2005.

[4] T. Sekozawa, "One to one recommendation system for apparel online shopping", *WSEAS Transaction on Systems*, vol.9, n°1, pp. 94-103, 2010

[5] W.K. Wong, X.H. Zeng, W.M.R. Au and P.Y.Mok, S.Y.S. Leung, "A fashion mix-and-match expert system for fashion retailer using fuzzy screening approach", *Expert Systems with Applications*, vol.36, pp. 1750-1764, 2009"2009.

[6] D. Vogiatzis, D. Pierrakos, G. Jenkyn-Jones and B.J.H.H.A. Possen, "Expert and community based style advice", *Expert Systems with Applications*, vol. 39, pp. 10647-10655, 2012.

[7] J. Li and Y. Li, "Cognitive model based fashion style decision making", *Expert Systems with Applications*, vol.39, pp.4972-4977, 2012.

[8] X. Zeng, Y. Zhu, L. Koehl, M.Camargo, C. Fonteix and F. Delmotte, "A fuzzy multi-criteria evaluation method for designing fashion oriented industrial products", *Soft Computing*, vol.14, n°12, pp. 1277-1285, 2010.

[9] Y. Zhu, X. Zeng, L. Koehl, "A general methodology for analyzing fashion oriented textile products using sensory evaluation", *Food Quality and Preference*, vol.21, n°8, pp. 1068-1076, 2010.

[10]S.Y. Baek M. Hwang, H. Chung and P. Kim, "Kansei factor space classified by information for Kansei image modelling", *Applied Mathematics and Computation*, vol.205, n°2, pp. 74-882, 2008.

[11]Y.F. Yuan and M.J. Shaw, "Introduction of fuzzy decision trees", *Fuzzy Sets and Systems*, vol.69, n°2, pp. 125 – 139, 1995.

[12]M.S. Khan and M. Quaddus, "Group decision using fuzzy cognitive maps for causal reasoning", *Group Decision and Negotiation*, n°13, pp. 463-480, 2004.

[13]L. Wang, X.Zeng, L.Koehl and Y. Chen, "From body measurements to human perception of body shapes: modelling using intelligent techniques", *International Journal of Advanced Operations Management*, vol.5, n°1, pp.74-90, 2013.