KEER2010, PARIS | MARCH 2-4 2010
INTERNATIONAL CONFERENCE ON KANSEI ENGINEERING AND EMOTION RESEARCH 2010

CHARACTERIZATION OF EMOTIONAL DESCRIPTORS FOR HUMAN BODY SHAPE DESCRIPTION USING SENSORY EVALUATION AND CLASSIFICATION OF BODY MEASUREMENTS

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ABSTRACT

This paper presents a new method for characterizing the relationship between emotional descriptors describing human body shapes and concrete body measurements. In order to generate different representative human body measurements, we create a set of virtual 3D human bodies with a CAD software. These virtual 3D human bodies can be used to simulate morphology of real body shapes from different angles. Next, for a specific application such as sport garments or professional suits, a procedure of sensory evaluation is organized so that a number of selected experts generate a list of relevant normalized emotional descriptors and then evaluate the virtual human bodies using these descriptors. From the body measurements taken from these virtual human bodies, we extract the most relevant geometric features for each normalized emotional descriptor. Based on the extracted features describing body shapes, we can effectively classify the virtual human bodies into several classes for each emotional descriptor and generate geometric criteria for a group of emotional descriptors by performing a data aggregation operation. The involved emotional descriptors and their evaluation results have been modeled using a cognitive map. Using the proposed method, a specific human body shape with a set of emotional descriptors can be realized by adjusting the corresponding geometric features or body measurements on the CAD software.

Keywords: *body measurements, emotional descriptors, body shapes, sensory evaluation, fuzzy cognitive map, decision tree*

1. Introduction

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In our everyday life, emotional descriptors such as “fat”, “slim” and “sportive” are usually used by general public and professional experts to describe human body shapes. In textile industry, a quantitative characterization of these emotional descriptors is very interesting for garment design. Based on these characterized emotional descriptors, we can more easily formalize the knowledge of garment designers and fashion designers on the relationship between body shapes and fabric materials and fashion styles of garments, and integrate this knowledge into a garment CAD system for proposing personalized products and suggestions to consumers. Actually, design and production of personalized products adapted to consumer’s evolutionary requirements on functionality, comfort and fashion style has become an important trend in many industrial sectors [1].

In this background, the characterization of human body shapes is particularly significant for realizing mass customization, i.e. quickly designing and producing new personalized products with minimal cost. In fact, relevancy of human body shape at the levels of comfort and aesthetics is usually considered as the most important criterion in development of new garment products. In garment design, the conformity between garment patterns and the specific body shape determines the level of comfort of the corresponding wearer. Many researchers have tried to integrate into the existing Garment CAD systems a number of functions permitting to modify patterns according to various body shapes [2]. Moreover, in fashion design, the conformity between fashion style of the garment and the specific body shape can enhance the cultural and social values of the wearer in different professional and social activities.

This paper presents a new method for characterizing emotional descriptors describing human body shapes using classification of body measurement. It permits to characterize the relationship between emotional descriptors describing human body shapes and concrete body measurements. In order to generate different representative human body measurements, we create a set of virtual 3D human bodies with a CAD software. These virtual 3D human bodies can be used to simulate morphology of real body shapes from different angles. Next, for a specific application such as sport garments or professional suits, a procedure of sensory evaluation is organized so that a number of selected experts specialized in garment design generate a list of relevant normalized emotional descriptors and then evaluate the virtual human bodies using these descriptors. From the body measurements taken from these virtual human bodies, we extract the most relevant geometric features for each normalized emotional descriptor. Based on the extracted features describing body shapes, we can effectively classify the virtual human bodies into several classes for each emotional descriptor and generate geometric criteria for a group of emotional descriptors by performing a data aggregation operation. The involved emotional descriptors and their evaluation results have been modelled using a fuzzy cognitive map. Using the proposed method, a specific human body shape with a set of emotional descriptors can be realized by adjusting the corresponding geometric features or body measurements on the CAD software.

The procedure of this study is composed of two parts, i.e. sensory data collection and formalization as well as analysis and mathematical modeling. In the first part, the procedure of sensory evaluation is organized at two levels. Level 1 is a conceptual evaluation. In this step, we define several fashion themes according to specific requirements of the market and then invite evaluators to generate a set of more concrete emotional descriptors describing each abstract fashion theme. For each fashion theme, the emotional descriptors given by different evaluators are unified by a round table discussion. Only relevant descriptors are preserved. Next, evaluators are invited to give a score to express the relevancy degree between each emotional descriptor and the corresponding fashion theme. In our experiment, the related fashion themes are "sportive", "healthy", and "attractive". 22 concrete emotional descriptors such as "bulgy-slim", "swollen-dented" and "forceful-atrophic" have been extracted to characterize these three fashion themes. These relationship degrees take five linguistic values, including "very irrelevant" (VI), "fairly irrelevant" (FI), "neutral" (N), "fairly relevant" (FR), "very relevant" (VR). Level 2 is an evaluation on virtual body shapes. In this step, evaluators are invited to express the similarity degrees when comparing each specific virtual body shape and a predefined standard sample on all the emotional descriptors. The previous similarity degrees also take linguistic values, including "extremely inferior" (EI), "very inferior" (VI), "inferior" (I), "a little inferior" (LI), similar (SI), "a little superior" (LS), "superior" (S), "very superior" (VS), and "extremely superior" (ES).

In the second part, the relationship between the fashion themes and the corresponding emotional descriptors is modeled using a fuzzy cognitive map [3], in which each arc represents an aggregated relevancy degree given by all evaluators. This aggregated relevancy degree is a fuzzy set, representing the evaluations scores of all evaluators. In general, cognitive maps can be considered as powerful tools for modeling a complex concept and its components as well as relations between different concepts. Using the proposed cognitive map, we can compare between different fashions and the understanding levels on fashion themes between two different publics, which is important to analyze the behaviors of consumers. The relationship between the emotional descriptors and the body measurements is modeled using a decision tree, which is more efficient to deal with linguistic data.

2. Sensory data acquisition and formalization

Let $T=\{t_1, t_2, \ldots, t_n\}$ be a set of n fashion themes characterizing the basic categories of body shapes relevant to the consumer public of the company. In our experiment, we have three fashion themes (n=3), i.e. "sportive", "healthy" and "attractive".

Let $D=\{d_1, d_2, \ldots, d_m\}$ be a set of m concrete emotional descriptors extracted by evaluators for describing the fashion themes in T.

Let $E=\{e_1, e_2, \ldots, e_r\}$ be a set of r evaluators evaluating the similarity between fashion themes and emotional descriptors and between emotional descriptors and body measurements.

The evaluation on the relevancy degree between a fashion theme t_i and an emotional descriptor d_j give by the evaluator e_k is expressed by x_{ijk}. During the evaluation, x_{ijk} is a linguistic value taken from {VI, FI, N, FR, VR}. For simplicity, we denote R_1=VI, R_2=FI, R_3=N, R_4=FR, R_5=VR.

For all evaluators, we obtain a distribution of their statistical evaluation results for all the linguistic values. In this case, the relevancy degree between the fashion t_i and the emotional descriptor d_j can be expressed by a fuzzy value distributed on the set {R1, R2, R3, R4, R5}, i.e.

$$X_{ij} = \left(\frac{NB(R_1)}{r} \quad \frac{NB(R_2)}{r} \quad \ldots \quad \frac{NB(R_5)}{r} \right)$$

where $NB(R_k)$ is the number of evaluators selecting R_k during the evaluation.

Evidently, the sum of all components in X_{ij} is 1.

The performance of X_{ij} can be characterized by the corresponding distribution. It is really a fuzzy set defined on five discrete values and quite different from a probability distribution because it does not deal with any random variable and its relation with the five discrete values is uncertain. The following principles should be taken into account. 1) If there exist more than one peak in the distribution of X_{ij}, then the evaluation results of different evaluators are diversified and the relationship between the fashion theme t_i and the emotional descriptor d_j can not be clearly identified by consumers. Otherwise, all evaluation data are centered on one peak and the relationship between t_i and d_j can be easily understood. 2) If the width of the distribution of X_{ij} is small, then the evaluation results for all evaluators are more concentrated and there is less ambiguity. Otherwise, the ambiguity is more important. In fact, these two principles are similar and the second is the refinement of the first. According to these principles, we formally define the performance criteria of the emotional descriptor d_j related to the fashion theme t_i by

$$V_{ij}^1 = NB\_peak(X_{ij}) \text{ and } V_{ij}^2 = Var(X_{ij})$$

In the previous definition, NB_peak(X_{ij}) and Var(X_{ij}) denote the number of peaks and the variance of the distribution in X_{ij} respectively.

These performance criteria are important in the following computation because they characterize the quality of evaluation data relating the emotional descriptor d_j to the fashion theme t_i. The performance of the fashion theme t_i can be evaluated by aggregating the performance values corresponding to all the emotional descriptors, i.e.

$$V_i^1 = \frac{1}{m}\sum_{j=1}^{m} V_{ij}^1 \text{ and } V_i^2 = \frac{1}{m}\sum_{j=1}^{m} V_{ij}^2$$

Low values of these criteria mean that the relationship between the fashion theme t_i and all the emotional descriptors is more easily understood by evaluators and the definition of t_i is more relevant to evaluators or consumers. Otherwise, the fashion theme t_i is less relevant for understanding of consumers.

Let B={B_1, B_2, …, B_h} be a set of h body measurement features characterizing human body shapes and W={W_1, W_2, …, W_p} a set of p virtual body shapes generated from the software LECTRA. Modaris 3D fit [4].

By taking measurements on all the virtual body shapes, we obtain the following results:
W_1: Y_1=(b_{11} b_{12} … b_{1h}), W_2: Y_2=(b_{21} b_{22} … b_{2h}), ……, W_p: Y_p=(b_{p1} b_{p2} … b_{ph})

The relationship between emotional descriptors d_1, d_2…, d_m and the virtual body shapes W_1, W_2 …, W_p is obtained by evaluating their linguistic similarity degrees related to a standard body shape. These similarity degrees take values from {EI, VI, I, LI, SI, LS, S, VS, ES} presented in Section 1. For simplicity, they are denoted by {C_1, C_2 …, C_9}.

For all the virtual body shapes, we have the following evaluation results:
W_1: (a_{11} a_{12} … a_{1m}), W_2: (a_{21} a_{22} … a_{2m}), ……, W_p: (a_{p1} a_{p2} … a_{pm})
where a_{ij} is also a fuzzy value distributed from C_1 to C_5. Its definition is similar with that of X_{ij}.

According to the same principles used for fashion themes, we also define the performance criteria in order to estimate the relevancy of the emotional descriptors related to each body shape and the relevancy of these body shapes.

3. Modeling sensory data using a fuzzy cognitive map

Cognitive maps or mental models are a type of mental processing composed of a series of psychological transformations by which an individual can acquire, code, store, recall, and decode information about the relative locations and attributes of phenomena in their everyday or metaphorical spatial environment. They are often used to graphically model a specific structure of knowledge or a set of concepts [5]. The complex relations between different fashion themes and between fashion themes and related emotional descriptors can also be modeled using cognitive maps. A Fuzzy cognitive map is a cognitive map within which the relations between the elements (e.g concepts, events, project resources) of a "mental landscape" can be used to compute the "strength of impact" of these elements. Fuzzy cognitive maps are signed fuzzy digraphs [3].

In this paper, a fuzzy cognitive map is used to model the relationship between the fashion themes in T and the emotional descriptors in D. It is a relevant technique for us because the relation between one fashion theme and one emotional descriptor is evaluated by a number of evaluators using different linguistic levels and then can be considered as a fuzzy set. Moreover, key emotional descriptors related to a specific fashion theme can be easily identified from the fuzzy cognitive map. The fuzzy sets X_{ij}'s (i=1, …, n and j=1, …, m) constitute the arcs relating the fashion themes to the emotional descriptors. The corresponding fuzzy cognitive map is given in Fig.1.

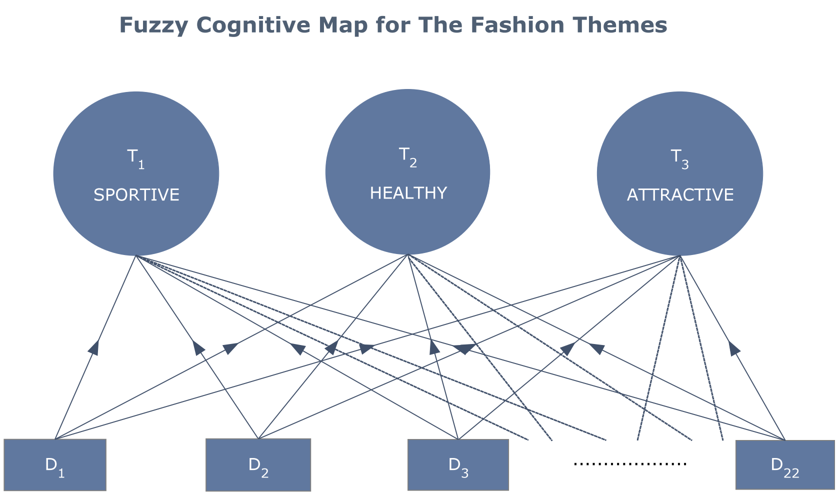


Figure 1: Modeling of the Fashion Themes Using a Fuzzy Cognitive Map

Taking the emotional descriptors as basic information representing fashion themes, we can analyze the relationship between them as follows. The dissimilarity of two fashion themes t_i and t_k is defined by

$$D_{ik} = Defuz(A_{ik}) \text{ with } A_{ik} = \frac{1}{m}\sum_{j=1}^{m}\left|X_{ij} - X_{kj}\right|$$

where Defuz(.) is a gravity center based defuzzification procedure and A_{ik} is obtained using classical additions and subtractions of fuzzy sets

If D_{ik} is closed to 0, the fashion themes t_i and t_k are close. Otherwise, these two fashion themes are quite different.

Also, using this dissimilarity, we can also determine if two different consumer publics (P1 and P2) have the same understanding on one fashion theme t_i. This difference permits to analyze the behaviors of consumers and predict if fashion styles in one market can be conform to another one. Assuming that the emotional descriptors are the same for P1 and P2, we define the dissimilarity of P1 and P2 related to t_i by

$$G_i(P1,P2) = Defuz\left(\frac{1}{m}\sum_{j=1}^{m}\left|X_{ij}(P1) - X_{ij}(P2)\right|\right)$$

The general dissimilarity for all the fashion themes is defined by

$$G(P1,P2) = \frac{1}{n}\sum_{i=1}^{n} G_i(P1,P2)$$

4. Modeling of the relationship between body measurements and emotional descriptors

The modeling of the relationship between the body measurements b_{ij}'s and the evaluations of virtual body shapes on emotional descriptors a_{ij}'s aims at solving two problems: 1) selecting the body measurements the most relevant to each emotional descriptor in order to understand better the semantics of these descriptors and the corresponding fashion themes in consumer public; 2) for each emotional descriptor, predicting values of emotional descriptors and fashion themes from the relevant body measurements.

Having measured or evaluated the body measurements and one emotional descriptor d_j for all the p virtual body shapes, we try to determine the relationship between them using a decision tree [6].

A decision tree is a hierarchical data structure in which nodes and branches represent attributes and their values respectively, and each leaf corresponds to one class of data or examples. It is frequently used for representing knowledge and generating decisions according to values of the attributes of a given object. A decision tree is built from a set of learning examples (couples of attribute/value) belonging to different classes. For a given object, the value of each attribute enables to know on which branch the object will be developed. A path from the root to one leaf corresponds to a set of attributes/values for determining the class of an object. It also corresponds to an IF – THEN rule permitting to deduce the belonging to one class from values of attributes. The whole set of the IF – THEN rules generated from a decision tree constitute the corresponding knowledge base. From a decision tree, we can identify the most relevant input variables related to one output variable and extract the relationship between the input and the output using these IF – THEN rules.

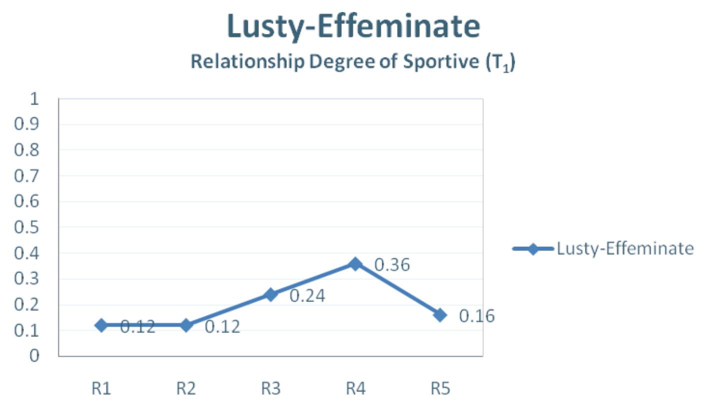
Decision tree is a data structure particularly adapted to linguistic attributes with limited values. Therefore, it can be used for deducing or predicting one emotional descriptor (d_j) from the body measurements (Yi's). In this paper, we build one decision tree using the C4.5 algorithm [6] (an entropy based method for selecting at each step the most relevant attribute maximizing the information gain) and a learning base composed of 12 data pairs of body measurements/emotional descriptor obtained from the generated virtual body shapes.

As the aggregated evaluation result related to the descriptor d_j is a fuzzy value distributed on a linguistic scale $\{C_1, C_2 \ldots\ldots, C_9\}$, we need to calculate the numerical mean value of this distribution using gravity center. For all evaluation results, these numerical values are used for building the decision tree.

5. Experiment and analysis of results

In the first level of sensory data collection, 25 evaluators (r=25) were invited to evaluate the relevancy degrees between 22 emotional descriptors (m=22) describing human body shapes and 3 fashion themes (n=3) using predefined linguistic values. These evaluators are young textile students from China (10 persons), France (9 persons) and other countries. Their ages vary from 20 to 30 years old. In the questionnaire, the selected emotional descriptors, frequently used by fashion designers, are given in English and their appropriate translations in French and Chinese so that each evaluator can have the same level of understanding on these words.

Figure 2: Distribution of the Relevancy degrees of "Lusty-Effeminate" related to the fashion



theme "Sportive"

Figure2 shows the distribution of the relevancy degrees given by all the evaluators on the emotional descriptor "Lusty-Effeminate" related to the fashion theme "Sportive". The number of peaks is 1 and the value of the variance of this distribution is low (0.0832). Therefore, we can consider that this emotional descriptor can be clearly identified by the evaluators without any ambiguity and it is rather relevant to the fashion theme "Sportive" because its peak is located to R4 (fairly relevant). In fact, this conclusion is conform to our common knowledge on sportive body shape.

From the sensory evaluation of level 1, a fuzzy cognitive map has been set up to characterize the relations between the fashion themes and the 22 emotional descriptors. It represents the understanding level of consumers on fashion themes used for garment design.

At level 2, 3 experts in garment design are invited to evaluate the similarity degrees between the 22 selected emotional descriptors and body measurements for a series of 12 various male virtual body shapes of Chinese population (p=12), generated by the software. These body shapes are obtained by combining 4 basic body types (Y, A, B, C) and 3 different height levels (155cm, 170cm, 185cm). These body shapes are represented by $W=\{W_1, \ldots, W_{12}\}$={CY 155, CA 155, CB 155, CC 155, CY 170, CA 170, CB 170, CC 170, CY 185, CA 185, CB 185, CC 185}. Moreover, 6 key body measurements (h=6) are selected, i.e. $BM=\{BW_1, \ldots, BW_6\}$={Stature, Arm Length, Chest Circumference, Neck Circumference, Waist Circumference, Hip Circumference}. These virtual body shapes can be dynamically visualized from any angle. During the evaluation procedure, we take CA170 as the standard sample for comparison with the other body shapes because this body shape is the most encountered in the related population. The comparison of the body shapes and the standard sample on each emotional descriptor lead to the generation of similarity degrees taken from $\{C_1, \ldots, C_9\}$ with C_1=--1, C_2=-0.75, C_3=-0.5, C_4=-0.25, and C_5=0, C_6=0.25, C_7=0.5, C_8=0.75, C_9=1. Finally, the decision tree with C4.5 learning algorithm is applied to the data set of similarity degrees for all body shapes and the corresponding body measurements for extracting rules charactering the relations between these two data sets. These extracted rules represent knowledge of garment experts on relations between emotional descriptors and body measurements, which can be further used for personalized garment design. Moreover, our experiment show that the difference in evaluation of virtual body shapes between these three garment experts is very small.

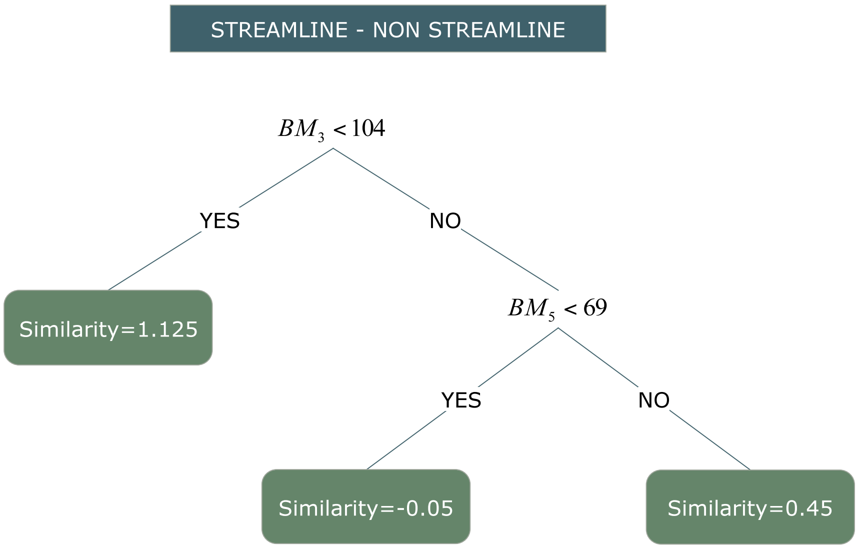


Figure 3: Decision Tree for Emotional Descriptor "Streamline-Non streamline" to Measurement

Figure 3 represents the decision tree characterizing the relation between the body measurements and the descriptor "Streamline". Two body measurements are relevant to this descriptor. They are "Chest Circumference" and "Waist Circumference". Moreover, 3 following rules are extracted from this decision tree:

Rule 1: IF (Chest Circumference < 104) THEN (Similarity = 1.125)

Rule 2: IF (Chest Circumference ≥ 104) AND (Waist Circumference < 69) THEN (Similarity = -0.05)

Rule 3: IF (Chest Circumference ≥ 104) AND (Waist Circumference ≥ 69) THEN (Similarity = 0.45)

According to Rule 1, if Chest Circumference is smaller than 104cm, then the corresponding body shape is between "a little streamline" and "very streamline". According to Rule 2, if Chest Circumference is bigger than 104cm and Waist Circumference is smaller than 69cm, then the corresponding body shape is between "a little non streamline" and "standard".

Another example is on the descriptor "muscular". The corresponding rules are:

IF (Chest Circumference < 104) THEN (Similarity = -0.75)

IF (Chest Circumference ≥ 104) AND (Stature < 162.5) THEN (Similarity = -0.44)

IF (Chest Circumference ≥ 104) AND (Stature ≥ 162.5) THEN (Similarity = -0.13)

6. Conclusion

This paper proposed two mathematical models for relating concrete human body measurements to abstract human body related concepts. The first model uses a fuzzy cognitive map for characterizing the relations between fashion themes and emotional descriptors describing human body shapes. The second model determines the relations between these emotional descriptors and concrete body measurements using a decision tree with the C4.5 learning algorithm. The relevancy of fashion themes and emotional descriptors can be analyzed from these models. Also using these models, body measurements can be semantically interpreted and classified using human evaluation data. Thus an abstract fashion style can be then associated with a number of concrete body shapes. The scientific contributions of this method can be summarized as follows. 1) It originally applies sensory evaluation techniques to virtual human bodies, permitting to classify body measurements using human perceptions. 2) It permits to automatically describe body shapes and related concepts using body measurements.

Based on these models, we can realize a computer-aided garment design system by exploiting the relations between body shapes, design elements and garment parameters in order to provide personalized suggestions on garment design and garment retailing.

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