

A Knowledge-based Approach for Personalised Clothing Recommendation for Women

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Abstract: Currently, recommendation system technology has been assumed as a promising approach to contribute to fashion domain in terms of electronic commerce. In this paper, we propose an approach for a clothing personalized recommendation system that is able to help the women to identify appropriate clothing categories together with models linked to clothing images, mainly based on their fashion styles and body types. To achieve this, besides an intelligent user interface, our recommendation approach deals with two main components: the user modeling and the clothing recommendation, which is responsible for recommending fashion clothing items to women. The user modeling is responsible for creating and updating the user model, including two main knowledge-based mechanisms: the first is responsible for automatically identifying the fashion style, and the second is responsible for detecting body type. We evaluated our recommendation approach and preliminary results indicate that it significantly supports the women with choices.

1 INTRODUCTION

There has been an increasing amounts of digital data and online resources in several domains readily available to users, forming a diversity of options to make choices. This is not a trivial issue, mainly when we are considering fashion domain. In recent years, particularly, there has been a rapid growing of fashion industry leading to very positive social and economic impacts worldwide in the global digital marketplace. Hence, this market segment has demanded academic research mainly in the fields of artificial intelligence (Russell, 2010) and visual computing, including computer vision and image processing in fashion domain (He and McAuley, 2016) and (Jagadeesh *et. al* 2014). In particular, recommendation system technology has been assumed as a promising approach to contribute to fashion context in terms of electronic commerce, suggesting clothing and other fashion items to users (Sha, 2016), therefore, facilitating and helping them on making appropriate choices.

Building personalized systems for clothing recommendation is a difficult task, mainly by considering the diversity of choice possibilities and styles. In this context, one relevant and challenging research problem is on how to make effective clothing recommendations to the users based on their personal characteristics. Unfortunately, in a broad sense, little research has been done on this issue, just some specific parts of this issue has been addressed, for instance fast item detection (Jagadeesh *et. al* 2014) and recognition (Sha, 2016) of apparel and accessories in real-world images, followed by search for similar items (Fukuda *et. al*, 2011) in online shops.

The present paper addresses the mentioned clothing recommendation problem by proposing an approach for clothing personalized recommendation system that is able to help the women to identify appropriate clothing categories together with models (here model means a kind of subcategory) linked to clothing images, mainly based on their fashion styles and body types. To achieve this, besides an intelligent user interface that unable the system to interact with the user, our recommendation approach

deals with two main components: the user modeling and the clothing recommendation, which is responsible for recommending fashion clothing items to women. The user modeling is responsible for creating and updating the user model, including two main knowledge-based mechanisms to generate relevant information to the user model: the first is responsible for automatically identifying the fashion style, and the second is responsible for detecting body type. Particularly, we have considered the five clothing categories (dresses, coats, tops, pants, skirt), five body types, and nine clothing fashion styles. Associated to each category, we define a clothing database containing a collection of models linked to women's clothing images in order to be filtered by the system and then help the user to select the appropriate clothing option. Here, it is important to state that this study belongs to a Project where we investigate the feasibility and the reachability of the use of such technology for clothing recommendation.

The rest of this paper is organized as follows. In Section 2, we provide some background knowledge and related work. In Section 3, we describe our approach for clothing recommendation. In Section 4, we discuss how our approach has been evaluated and the current obtained results. Some conclusions and proposal for some future work are presented in Section 5.

2 BACKGROUND KNOWLEDGE AND RELATED WORK

This section presents some background knowledge relevant to understand the proposed approach for clothing recommendation. Moreover, we discuss some related work.

2.1 Some Clothing Fashion Concepts

2.1.1 Overview of Body Types

The female body types are differentiated by the basic combinations of the measures of the shoulder, the waist and the hips. We emphasize here that we are not focusing their size, only the symmetry of the apparent combination between them. Basically, we highlight the following models and their proportions, and in this case, most women fall into one of five body types:

i) Hourglass: The measurements of the shoulders and hips are practically the same, presenting the different

measures of the waist, being able to be only demarcated or much narrower than the other measures, that is, curvy but evenly proportioned;

ii) Inverted Triangle or Apple: In this female body type the measurement of the shoulders is greater than the waist measurement and the hips;

iii) Triangle or Pear: This female body type has narrower shoulders and waist thin than hips, that is larger at the bottom;

iv) Rectangle: This format shows the measurements of the shoulders of the waist and of the hips being practically the same, without many variations of the measures, that is straight up and down; and

v) Oval: This type of female body is highlighted by the width of the waist is much larger than the measured shoulders or hips.

2.1.2 Overview of Clothing Fashion Styles

The concept of style originates in the Latin term *stilus* which, in turn, derives from the Greek language. On the other hand, habitual use refers to the taste, elegance, or distinction of a person or thing. Thus, in this work, we call "fashion style" the way each person dresses and their preferences for pieces of clothing, accessories and the image they want to convey (Aguiar, 2003).

We describe below, in a very simplified way, the 9 main fashion styles that served as the basis for the present recommendation system:

i) LadyLike: This style transmits romanticism and sweetness. It is characterized by light colors, delicate prints, marked waist and details of laces, lace and ruffles;

ii) Classic: It refers to the name given to the style that does not change due to trends, being a more conservative and formal style;

iii) Rocker: It transmits boldness and it is generally highlighted by dark colored pieces, plaid, leather, studs and torn;

iv) Casual: It is characterized by the union of classic and informal parts. It is versatile and very bare;

v) Glam: It has characteristics like clothes with soft lines, delicate jewelry, stiletto heels, sequins and luxury items;

vi) Cool: It is characterized by the use of parts that are always in fashion and the overlap of parts;

vii) Boho: It has as main element the comfort. It is characterized by wide and fluid parts with light fabrics and earth elements;

viii) Sexy: Transmits sensuality by showing some parts of the body with just and short parts;

ix) Activewear: Style of clothing intended for sporting activities.

2.2 Overview of Recommender Systems

Recommender systems (RS) are software applications that aim to find the information or product or even people that matches the user needs and preferences, often attempting to reduce information overload (Resnick, 1997). These systems have proved to be helpful tools for various information seeking and filtering tasks on several domains on the Web, for instance in films, music, books (He and McAuley, 2016). Their main goal is to recommend items of interest to the end users based on their preferences and other data collected. To achieve that, most Recommender Systems exploit the collaborative and content-based filtering approaches, but there are other approaches, for instance Demographic Filtering, and utility and knowledge-based approaches (Fukuda *et. al*, 2011).

In the present research work, we are focusing on knowledge-based recommender systems, mainly involving knowledge representation and reasoning techniques from the field of artificial intelligence. Such systems make decisions and provide items or services suggestions to users, according to their preferences and needs and the knowledge representation of the application domain. Therefore, this kind of system generates recommendations to a user by consulting its knowledge base of the product domain, and then reasoning what items will best satisfy the user's requirements.

2.3 Related Work

Some previous work in the literature related to clothing recommender system has focused on collaborative filtering approach (He and McAuley, 2016). Following the line of fashion coordination support systems, the work in (Fukuda *et. al*, 2011) proposes a recommender system called Talking Closet, which considers the user preferences to suggest clothing combinations according to the user closet, automating the daily cloths choice process. In (Qingqing *et. al*, 2010), the authors describe a recommender system for helping customers to find their most suitable fashion choices in mass fashion information in the virtual space based on multimedia data mining from the Web. This system considers some characteristics of the users, such as: color preferences and clothing styles, as well body parameters like skin tone. With a different proposal,

by directly considering fashion domain knowledge, the work in (Vogiatzis, 2012) proposes a knowledge-based recommender system for style advice in the fashion domain, taking into account the knowledge of domain expertise and user interaction data with fashion sites. The present work is very similar to the work in (Resnick, 1997) in the sense that it also has invested in a knowledge-based approach for recommendation. However, this work differs from the other mentioned works, mainly in terms of the used recommendation approach.

3 THE PROPOSED RECOMMENDATION APPROACH

In this section we discuss our approach and describe the system architecture with its main components, as well as, we describe the interactions between these components. Moreover, we provide an overview about implementations aspects of this recommendation system.

3.1 Preliminary

Our approach for personalized clothing recommendation to women is mainly based on their fashion styles and body characteristics. It firstly consists of creating and initializing with personal data of a user model and subsequently executing mechanisms to be performed in four main steps: the first is responsible for automatically identifying the fashion style, and the second is responsible for identifying the user's body type. The third is responsible for mapping pairs formed by fashion style and body types into clothing models associated to categories and finally, the fourth is responsible for recommending clothing models associated with clothing images for the women, taking into account the clothing categories linked to a selected pair <body type, fashion style> from a relationship between a body type set and a fashion style set. Thus, associated to each category, we have clothing models with several linked to women's clothing images, forming a clothing database.

3.2 The Architecture

The recommendation system architecture, as shown in Figure 1, consists of the following main components: **Intelligent User interface, user modeling** with the modules fashion style engine and

body type selector, **clothing recommender** with models and clothing images, as well as **three knowledge bases** and a **clothing images database**. The proposed recommendation system was mainly designed following the conceptual architecture of a classical knowledge-based system.

Before going to describe each one of these components, let us first to present a formalization of some sets used in the recommendation system. Let S , C , BT , and BP be four nonempty sets, where: $S = \{s_1, s_2, \dots, s_n\}$, n is the cardinality of S , that is, the number of elements that belong to S , and S denotes a set of clothing fashion Styles; $C = \{c_1, c_2, \dots, c_k\}$, k is the cardinality of C , and C denotes a set of clothing Categories; $BT = \{bt_1, bt_2, \dots, bt_5\}$, denoting a set of Body Types; and $BP = \{bp_1, bp_2, \dots, bp_m\}$, m is the cardinality of BP , and denotes a set of Body Parameters; $M = \{m_1, m_2, \dots, m_t\}$, t is the cardinality of M , and M denotes a set of clothing Models associated with the categories; $IM = \{im_1, im_2, \dots, im_s\}$, s is the cardinality of IM , and IM denotes a set of clothing images associated with the models.

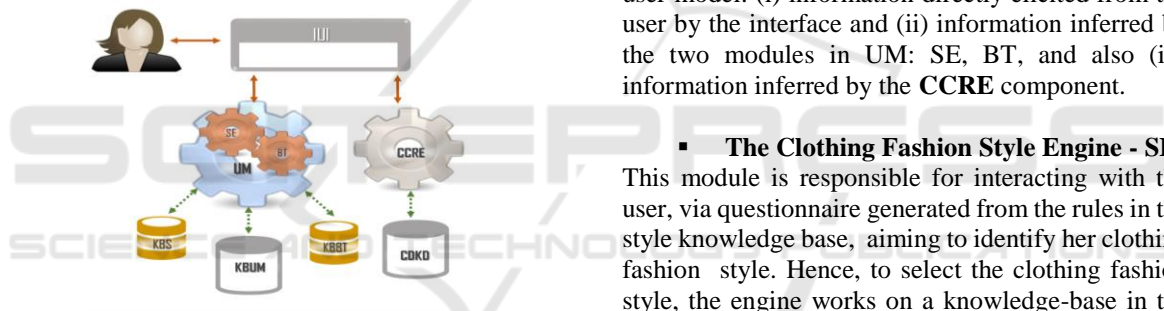


Figure 1: Recommender System Architecture.

3.2.1 The Intelligent User Interface (IUI)

This component has the responsibility of interacting with the user and with the rest of the components of the recommendation system. Thus, the user interacts with the recommendation system via IUI, which provides overall control over the whole process. This component includes question-answer facilities that are generated by the engines in the architecture, enabling the system to interact with the user for the purpose of asking questions and providing answers. It is a kind of intelligent interface that includes a controller mechanism playing the role of the control of interactions in the recommendation system, working as an intermediary between the user and the two components: User modeling and Clothing Recommendation Engine involving clothing categories, models with clothing images. It takes the responsibility for controlling the interactions among

the components and presenting information to the user or to getting information from the user. It contains rule interactions with knowledge about the system components, that is, a kind of meta-knowledge on the other components of the recommendation system, having the meta-rules for interacting with the user. Then, the main functions of the controller are to interpret the user action and to select the appropriate component for acting, to coordinate the operations of the five components, and to interact with users. Hence, it is able to recognize all actions that a user or any component might produce, and deciding what action should be taken. Thus, IUI uses, for instance, rules in the form **IF** the current user action is about the task T_i **THEN** call component i .

3.2.2 The User Modeling - UM

This component is responsible for creating and updating the user model. To achieve this, it requests and stores in the KBUM knowledge base from the user model: (i) information directly elicited from the user by the interface and (ii) information inferred by the two modules in UM: SE, BT, and also (iii) information inferred by the **CCRE** component.

- **The Clothing Fashion Style Engine - SE**

This module is responsible for interacting with the user, via questionnaire generated from the rules in the style knowledge base, aiming to identify her clothing fashion style. Hence, to select the clothing fashion style, the engine works on a knowledge-base in the form of production rules and then, sometimes, by asking questions to the user, keeping user's responses in a working memory. Therefore, from these rules and user's inputs, the SE makes a decision about user's fashion style. Its inference engine uses backward chaining to explore the rule base.

Formally, SE can be defined as follows:

Input: a rule base and some pairs <attribute, value> obtained from the questionnaire answered by the user taking into account questions from the rules asked her.

Process: Rule-based inference Engine.

Output: $si \in S$, representing a single element from S .

- **The Body Type Selector - BTS**

This module is responsible for selecting the user's body type.

Formally, **BTS** can be defined as follows:

Input: rule base and set of values for the used body parameters.

Process: Inference on a set of IF THEN Rules.

Output: bt_j , representing a specific body type.

3.2.3 The Clothing Category Recommender Engine - CCRE

This component is responsible for providing users with personalized clothing recommendation containing to each category a collection of models with linked clothing images, based on the relationships that exist between her body type information and her fashion style. The representation of the clothing domain knowledge is in the form of production rules with their conclusions parts containing actions to query a table and to generate a clothing recommendation output, according to the use of an inference engine, which explores the rules. Mathematically, using the relation notation, we can express the recommendation system (rs) as follows: $rs: (S \times BT) \rightarrow ((C \times M) \times IM)$.

Formally, CCRE can be defined as follows:

Input: rule base and a table with pairs $\langle bt_j, si \rangle$ mapping into $\langle C, \text{set of models to each category, set of clothing images to each model} \rangle$, meaning a pair containing a particular body type and a particular fashion style.

Process: rule-based inference engine with output actions to query to the decision table containing styles versus body types linking with each clothing category and associated clothing model with a collection of images.

Output: clothing category, from the cartesian style and body type, associated with clothing models linked to a collection of clothing images.

3.2.4 The Knowledge Bases and the Clothing Database

User Model as Knowledge Base: A user model is a representation of the user characteristics that may be relevant for her interaction with the recommendation system. Thus, this component stores information about the user, as a kind of internal representation of her. We have considered body parameters like skin color, hair color, waist, bust, hip, height and weight, where such information is obtained when the user is asked by the system by means of a form filled. Additionally, there is other information about the user's characteristics and that is also updated in each recommendation session. It is captured, by a dynamic user modeling component, according to the inference

processes and to the function computation. The knowledge is represented by facts with pairs $\langle \text{attribute, value} \rangle$ expressed in a relational database.

Fashion Clothing Style Knowledge Base via Rules(KBS): This knowledge base contains a collection of 41 IF-THEN production rules and a connected working memory, to be used together by the inference engine, allowing to answer question on what is the fashion style of a given user. These rules were directly obtained from a constructed decision tree.

Clothing Domain Knowledge via Rules(CDKD): This knowledge base contains a rule base and an associated decision table involving a relationship between styles and body types, mapping into clothing categories linked to models and clothing images collections. In this case, an example of rule from Knowledge Body Type is **IF** BodyType = hourglass **and** Style = LadyLike **THEN** skirt1=Eve **and** skirt2=Flared, where a particular body type and style yields two models for the category skirt. Each model is linked to a collection of clothing images.

Clothing Database: It contains collections of models associated with each clothing category, and a set of women's clothing images connected to each one of those models.

3.3 Overview of User-System Interactions

The interaction process begins when the user accesses the system and then starts a basic dialogue with the interface component. The interface first checks if the user is entering in the system for the first time. If so, it requests the user modeling to create the user model with her profile. Next, after this basic registration with some personal data, the system continues the interaction process as follows.

In general, from now on, the interaction between the user and the system in the recommendation process of clothing is achieved taking into account interaction components that deal with physical characteristics and with fashion styles. Then, the full recommendation process is performed by following three main steps: first, the system, via user modeling, identifies the user's style based on the execution of the SE module working on the Fashion Style Knowledge Base and on the user's answers to the questions generated by the processed rules. The second, the system, via user modeling, uses body parameters of the user to infer the user's body type.

The third, the recommendation system uses the output of the first and second steps to select clothing categories with models linked to clothing image collection, associated with each category, which matches with the identified fashion style and a particular body type.

3.4 Design and Implementation Aspects

This section explains the implementation of the recommendation system, in line with the architecture and description presented. We first discuss the used knowledge bases considering acquisition and knowledge representation aspects, as well as, the database solution. Then, we discuss the used rule-based inference engines. In general the recommendation system is implemented in Java technology, by considering the multiplatform characteristics of this technology, and as a database implementation we used relational database technology adopting MySQL as a database management system.

3.4.1 Knowledge Bases and Inference Engines

Our approach involves the design of a recommendation system using knowledge expressed in three knowledge bases represented by production rules. Specifically, to model the knowledge about fashion styles we first used a decision tree and then mapped this tree into a set of **If-Then** statements for the development of the rule-base. To model the knowledge about body types, as well as the knowledge for clothing recommendation, we used a set of If-Then rules. Thus, as discussed before, three rule-based systems have been designed, one for the inference of fashion style, other for the inference of body type, and finally, another to clothing recommendation. We have focused on utilizing expert knowledge bases to detect both fashion style, to identify body type, and to clothing recommendation. The knowledge base for the style detection was stored as related tables in a relational database using MySQL. The rule has the following structure: IF preconditions THEN action, where the rule's preconditions and action are expressed in terms of triples <attribute, operator, value>, denoting: (1) the preconditions (IF) that involves a set of conditions to be satisfied; (2) the consequent (THEN) that contains actions to be executed or new knowledge to be produced if the consequent is true. The knowledge base for representing body types knowledge is also

expressed in If-Then rules. Moreover, the clothing knowledge base is also expressed in If-Then rules, as illustrated in one example in 3.2.7.

The inference engine uses rule chaining with backward chaining algorithm to obtain its conclusions. In general the recommendation system is implemented in Java technology, by considering the multiplatform characteristics of this technology. We implemented the three used inference engines using the rules Engine Drools shell that is implemented in Java, allowing easy integration with some module written in Java. It is possible to invoke Java methods from Drools and vice versa. This enables us to develop more powerful and flexible rules.

3.4.2 Clothing Database Model

It contains a set of models and a set of women's clothing images connected to each one of those models, which then are associated with each clothing category. In this database model we represent the main relations in the system, as well as, the relationship among them. Thus, in Figure 2 is presented part of the relational database model containing the following relations: style, style_has_category, category, bodytype, bodytype_has_category, models and images. The Style relation stores data related clothing styles and each style has one or more categories, as represented by the Category relation, as well as, the same category can be in more than one style. The BodyType relation represents the body types and can be associated to more than one category and vice-versa. Moreover, there is a transitive relationship among the relations Category, Models and Images, and in this sense, a category has one or more models and a model has one or more clothing images.

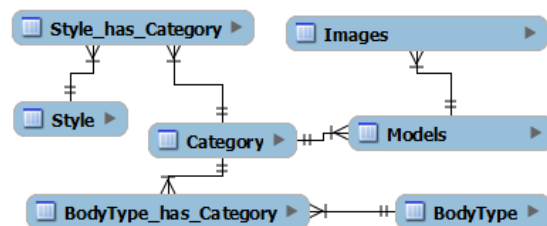


Figure 2: Clothing Database Model.

4 PRELIMINARY EVALUATION AND RESULTS

In this section we are going to describe a preliminary experiment, involving twelve women, we have conducted to evaluate our approach. The main purpose of this experiment is twofold: (i) to evaluate the quality of the knowledge bases for fashion styles and for body types of the system in terms of their accuracies and (ii) to measure if the recommendation system significantly helps the users to find suitable clothing choices.

The participants of this experiment consisted of 12 women, where all of them are between 22 and 30 years of age, as well as, 8 are undergraduate students from a public university and 4 have a graduate degree. Additionally, in this study we have a support of a Personal Stylist. We explained to each participant the procedure of the experiment and what kind of data would be collected, as well as, the aim of the experiment. In Table 1, there are two examples of body measures of two women W1 e W2 that participated in the experiment. The data in the table were used as input to the body type engine in order to it infer the body type of the women.

Table 1: An example of inputs to detect body type: Body measures for each woman.

Women	Bust	Waist	Hip	Height	Weight
W1	92.5	69.4	83.5	1.65	57
W2	109.4	112.00	98.4	1.69	85

Additionally, the system was tested by one personal stylist aiming to check its functionality in different scenarios to cover a variety of situations.

Table 2: Example of agreement degree between the system inferences and Stylist opinions, regarding body type and clothing style.

Women	System Output		Personal Stylist Opinion	
	Body Type	Style	Body Type	Style
W1	Apple	Ladylike	Apple	Classic
W2	Hourglass	Glam	Hourglass	Glam

In Table 2 is an example from the experiment to illustrate the input and output of the system and of the stylist opinion, concerning data of two women with respect to the identification of body type and of fashion style. There was a total agreement with regard to the detection of body type. However, concerning the style, there was a little divergence between the

two evaluations, once that to W1 the system assigned to "Ladylike", whereas the stylist assigned to "Classic". Such divergence, however, was explained by the expert, considering that the two styles are very close in terms of some similar characteristics.

All participants answered all the proposed questions. Overall, this brief evaluation indicated that the system is feasible (meaning that it works: In all the input-output tests accomplished, the results were satisfactory) and that all participants mentioned that they found the clothing recommendations useful and that the information contained in the recommendations helped them to improve their understanding about fashion clothing domain. Women also agreed that the system is useful. But, concerning the comparison between the system output and the stylist opinion, there was some disagreement between them with respect to style, in just two situations among twelve. This situation, however, was not considered a relevant problem to the system quality in terms of its accuracy.

5 CONCLUSION AND FUTURE WORK

In this paper, we presented a personalized approach for clothing recommendation, explaining how the system generates personalized recommendations for women. We reported the first evaluation results, showing that the quality aspects of the constructed knowledge bases and then the significant help provided by the recommendations to the users. But, of course, even with preliminary positive results until now, there is an urgent need for more and more evaluations with the same experiment to better test the system, involving other users with more different characteristics.

As immediate future work, we will focus on provide more experiments toward better understanding and limitations of the proposed approach. In parallel, we will extend the recommendation system by including one more filter in the last phase in order to promote more specificity in the clothing recommendation, as well as we will improve the user model in its dynamic information part to capture other user's preferences and characteristics.

REFERENCES

- Russell, S. and Norvig, P. *Artificial Intelligence: A Modern Approach*. Pearson, third edition, 2010.
- R. He and J. McAuley. *Ups and downs: Modeling the visual evolution of fashion trends with one-class collaborative filtering*. In *WWW 2016: 25th International World Wide Web Conference*. 2016.
- V. Jagadeesh, R. Piramuthu, A. Bhardwaj, W. Di, and N. Sundaresan. *Large scale visual recommendations from street fashion images*. August 2014, KDD'14: Proceedings of the 20th ACM SIGKDD international conference on Knowledge discovery and data mining.
- Dandan Sha et. al, 2016. *An Approach for Clothing Recommendation Based on Multiple Image Attributes*. Springer Book chapter: Web-Age Information Management, Volume 9658 of the series Lecture Notes in Computer Science, pp 272-285.
- Fukuda, Mio; Nakatani, Yoshio. *Clothes Recommend Themselves: A New Approach to a Fashion Coordinate Support System*. Proceedings of the World Congress on Engineering and Computer Science (WCECS), 2011.
- Aguiar, Titta. *Personal Stylist: guia para consultores de imagem*. São Paulo: Editora Senac São Paulo, 2003.
- Resnick, Paul; Varian, Hal R. *Recommender Systems*. Communications of the ACM, ACM, New York, Ny, USA, Vol. 40, n° 3, p. 56-58, March, 1997.
- Qingqing, Tu; Le, Dong. *An Intelligent Personalized Fashion Recommendation System*. In Proceedings of the International Conference on Communications, Circuits and Systems (ICCCAS), 2010, pp. 479–485.”
- D. Vogiatzis, et. al., 2012. *Expert and community based style advice*. Expert Systems with Applications: An International Journal, vol. 39, no. 12, pp. 10647–10655, September 2012