An ontology based personalized garment recommendation system

Stuti Ajmani, Hiranmay Ghosh  
TCS Innovation Labs, Delhi  
TATA Consultancy Services Limited  
Gurgaon 122003, INDIA  
Email: {stuti.ajmani | hiranmay.ghosh} @tcs.com

Anupama Mallik, Santanu Chaudhury  
Department of Electrical Engineering  
Indian Institute of Technology, Delhi  
New Delhi 110016, INDIA  
Email: ansimal@gmail.com | santanuc@ee.iitd.ac.in

Abstract—We present a novel method for content-based recommendation of media-rich commodities using probabilistic multimedia ontology. The ontology encodes subjective knowledge of experts that enables interpretation of media based and semantic product features in context of domain concepts. Our recommendation is based on semantic compatibility between the products and user profile in context of use. We use probabilistic knowledge representation and reasoning framework to achieve robust and flexible results. The approach has been validated with fashion preferences of several individuals with a large collection of Sarees, an ethnic dress for women in Indian subcontinent.

Keywords—multimedia, ontology, fashion, recommendation, reasoning

I. INTRODUCTION

Selection of media-rich products, such as apparel, jewelry, music and movies, on a shopping portal is a daunting task. Selection of such commodities are generally guided by their aesthetic values. Product catalogs commonly available on the portals do not alleviate the need for audio-visual inspection of a large number of items. A personal recommendation engine for such commodities should help a user in the selection process by identifying a small subset of products that are likely to be suitable in the given context of use. While doing so, the system should provide for enough flexibility to cater to variations in aesthetic and artistic values of different users. This makes recommendation of media-rich products significantly more complex than that for other products. In this paper, we present a new ontology based approach for recommendation engines for media-rich products that cater to such flexibility and its application to garment recommendation.

Majority of recent research on recommendation systems have used Collaborative Filtering technique using some k-NN approach [1], where the recommendation set is restricted to the well-established products. A few researchers [2], [3] have proposed use of ontology to establish similarity between products in terms of their contents, primarily to alleviate this cold-start problem. These systems learn the user preferences from past shopping behavior of the users or their peers. A distinct ontology based approach for apparel recommendation has been proposed in [4], where the ontology encodes the expert view on fashion. However, the crisp association rules employed in the system makes it inflexible. Further, while recommendation systems for media-rich commodities, especially for music and movies, dominate the research space [1], none of them exploit the semantics of the media features of the products in making the recommendations. Our primary contribution in this paper is to provide a new approach to ontology based recommendation system, which employs Content based Filtering. Semantic analysis of product features, especially the media features, in context of use is a novelty in our approach. We have created a prototype for apparel recommendation with a collection of Sarees\(^1\) to validate our approach. We have encoded the ontology using a new ontology language, MOWL [5], that enables the analysis of visual properties of garments with respect to fashion concepts. The probabilistic knowledge representation and reasoning scheme used in our approach makes the system flexible and robust. We have established the performance of our engine by comparing the recommendations made with the actual choice of a number of individuals, including celebrities.

The rest of the paper is organized as follows. Section II presents a brief introduction to MOWL, the multimedia ontology representation scheme used in the system. Section III presents a fashion ontology. The reasoning scheme has been discussed in section IV. Section V presents and analyzes the results for experimental validation. Finally, we conclude the paper in section VI.

II. A BRIEF DESCRIPTION OF MOWL

Robust concept recognition in multimedia documents requires interpretation of the media properties in a domain context. Traditional ontology representation schemes cannot reason with the unique properties of media features of concepts. An alternate scheme for ontology representation for multimedia applications, Multimedia Web Ontology Language (MOWL) [5], is based on a causal model of the world, where abstract concepts are believed to manifest into specific media properties in multimedia instances. There is always some uncertainty associated with such media manifestations. The uncertainty can be represented in the ontology in terms of a set of Conditional Probability Tables (CPT’s) for the media properties. Concepts are inferred from the observed media properties using the principle of best explanation.

Further, the ontology representation scheme enables reasoning with media properties of the concepts related in a domain context. For example, a garment made of silk is expected to “inherit” the shininess property of the latter. An

\(^1\)Saree is an ethnic garment, commonly worn by women in Indian subcontinent. Please see the section on experimental validation for illustrations.
Observation Model (OM) for a concept, comprising a large set or redundant media property descriptors, can be created by using such reasoning techniques. An OM is organized as a Bayesian network and can be used for probabilistic reasoning. The ontology representation scheme also supports formal representation of spatio-temporal relations that are likely to exist between observed media features, in context of a concept. The ontology representation and reasoning schemes are generic and is independent of the media types and application domains.

![Ontology for Fashion Recommendation](image)

**III. Ontology for Apparel Recommendation**

A person is said to be well-dressed, when the visual properties of the dress chosen blend well with the visual properties of her personality in context of an occasion. A fashion ontology encodes the semantics of such “blending”. Figure 1 depicts a small section of a fashion ontology. The domain concepts are shown as ellipses and their observable media properties are shown as rectangles. In the diagram, we show one garment class, Saree, which we shall be dealing with in our prototype implementation. Other garment classes can similarly be included. While the garments are generally characterized by several properties, such as fit, color, material and craft, all of the properties may not be relevant for each class of garments. For example, the property “fit” is not applicable to Sarees, since they can be wrapped around the body in different ways to suit different body shapes. The brown arrows in the diagram indicate expert views for association of garment properties with personality and occasion attributes; such associations are probabilistic in nature. For example, the link `occasion → material` implies that the choice of material is guided by the occasion of wear. A Conditional Probability Table (CPT) associated with each of such links indicates such preferences, e.g. silk for parties and cotton for casuals. They can be obtained either empirically (expert opinion), or through analysis of classifications used in multiple shopping portals.

We have used MOWL to encode the domain knowledge, since it supports encoding of media properties of concepts with conditional probabilities and enables reasoning with such media properties. While we have included only a few garment properties in the ontology to illustrate the principles, the domain knowledge can be extended by including other properties, as well. It is important to note that the ontology, in its general form, is independent of any particular garment type or any specific garment collection. It can be reused by stores selling different kinds of garments in their collection.

**IV. The Reasoning Model**

The reasoning model of MOWL comprises creation of Observation Models (OM’s) from the media property descriptions of related concepts. An OM is organized as a Bayesian Network, which is used for concept recognition using abductive inferencing. The reasoning for apparel recommendation is done in two stages:

![Reasoning for Color Season](image)

**A. Determining personality**

Visual personality of an individual is represented through the concepts like her color season and her body shape. Observation of the body colors of a user provides evidence for her
color season. We create an $OM$ in the form of a naïve Bayesian network as shown in figure 2 by using a section of the ontology that associates these entities. The root node $C$ in the figure represents the Color Seasons with a state corresponding to each color season value, e.g. “Spring”, “Winter”, etc. Each of the leaf nodes represent a specific skin ($S_1, S_2, \ldots$), hair ($H_1, H_2, \ldots$) or eye ($E_1, E_2, \ldots$) color. The conditional probabilities for the body colors are obtained from the ontology. In absence of any prior knowledge, equal prior probabilities are assigned to each of the states of the root node. It is possible for the system to learn a realistic distribution over prolonged usage.

We analyze the facial image of the user to derive the dominant body colors and instantiate the corresponding leaf nodes in the Bayesian network. The posterior probability distribution for the root node signifies the relative traits of the color seasons for the user. We have observed that a person generally exhibits traits from more than one color seasons, a few of which are significant. The body shape of a user can be similarly reasoned using her body measurements.

B. Garment recommendation

At the next stage of reasoning, the ontology is used to create an $OM$ to find a suitable garment in a given context of use, that comprises user personality and occasion. Correspondingly, the $OM$ depicted in figure 3 has $X$ (context) as the root node with two children $P$ (personality) and $O$ (occasion). The personality, in general, manifests itself in user color season profile ($UC$) and user body shape profile ($UB$). The color season profile is a probability distribution over the different color season values. Further, the user color season $causes$ a set of garment colors to be suitable for a user. Therefore, the $OM$ is extended to include the various possible garment colors $G_1, G_2 \ldots$ as children of $UC$. These nodes are dynamically conditioned based on the user color season profile as follows:

$$P(u(C) = \{p_u(c_1), p_u(c_2) \ldots p_u(c_N)\})$$

where $p_u(c_i)$ represents the probability of the user to belong to color season $c_i$. Let $G_i$ represent the set of garment colors associated with color season $c_i$. Let us define a function $\delta_{ij}$ as $\delta_{ij} = 1$ if $c_i \in G_j$ and 0 otherwise. Now, the conditional probabilities in the CPT are given by $P(G_i|U) = \sum_j p_u(c_i) \times \delta_{ij}$ and $P(G_j|\neg U) = \frac{1}{n_c} \sum_i (1 - p_u(c_i)) \times \delta_{ij}$. Similarly, the $OM$

could be extended to include different garment fits (“tight-fit”, “loose-fit”, etc.) as children of $UB$ and the conditional probabilities can be dynamically computed in accordance with user body shape profile. The “occasion” may either be explicitly specified or implicitly inferred from the events on a Social Network calendar. In general, the occasion profile can also be a probability distribution over various possible values. We extend the $OM$ to include the various garment properties that are affected by occasion, e.g. material ($M_1, M_2, \ldots$) and craft ($F_1, F_2, \ldots$) as children of $O$ and compute the conditional probabilities for these nodes in a similar way.

After constructing the Bayesian network, every garment instance in the virtual store is examined. The garment colors are obtained from the garment image and the other properties are obtained from the garment metadata. Some of the leaf nodes in the Bayesian Network, depending on the observations, are instantiated. The garments that are best explained by the context, as indicated by the posterior probability of the node $X$, are selected for recommendation.

It should be noted that we are interested in relative (and not absolute) probabilities, any prior probability can be used for the context node $X$. In absence of any other preferences, it should be the same for all garments to be analyzed. However, if the $à$-priori relative preferences for the items (e.g. brand preferences) are obtained by collaborative filtering technique, the prior probability for the node $X$ can be assigned accordingly. Thus, it is possible to integrate content based and collaborative filtering attributes seamlessly in the reasoning model, resulting in a hybrid recommendation system.

V. EXPERIMENTAL VALIDATION

We have created a prototype recommendation system using approximately 200 Sarees by borrowing the images and meta-data from a leading on-line portal. We have used dominant color and color histogram features using HSV color model to characterize body and garment colors in the ontology. We have analyzed the facial images of individuals to discover their color seasons and to recommend Sarees for them for two different occasions. We have compared these recommendations with actual preferences of the individuals. We have done two sets of experiments, (a) with several well-known Indian celebrities and (b) with several anonymous persons.

A. Validating with celebrities

In this experiment, we have used the face images of several Indian celebrities and made recommendations for them. We have compared the recommendations with the Sarees actually worn by the celebrities. Figure 4 shows the results for one of the celebrities. The top rows in the figure shows the face image used for determining color season and the discovered color seasons distribution. The next row shows some randomly picked images of that celebrity in Saree. The last two rows show our recommendations for the celebrity for two different occasions. We note that while silk is generally recommended for party-wear, the casual-wears are recommended from a variety of lighter materials. This is consistent with common-sense knowledge. The colors chosen for the recommended Sarees mostly match those actually worn by the celebrities.
This validates our approach for recommendation based on probabilistic reasoning with the color season model.

B. Validating with anonymous subjects

We selected ten subjects and recommended Saris for two occasion categories based on color season analysis of their face images. We requested the subjects to provide ratings for the Saris with respect to their subjective preferences on a four-point scale (4 representing the highest and 1 the lowest on the scale). Table I depicts the average ratings provided by the subjects. We see a significant variance in the ratings (especially for the casuals), which matches with our expectation, since fashion preferences are quite subjective. Nevertheless, the median ratings of 3+ for both the categories validate our recommendation scheme.

C. Robustness

The probabilistic reasoning employed in the system helps in achieving robust and flexible results as compared to the crisp reasoning technique employed in other ontology based recommendation systems. For example, it is possible to discover traits of different color seasons in a person, e.g. in figure 4, which leads to recommendation of a wider choice of colors, which would not be possible with crisp reasoning scheme as in [4]. In a few extreme cases, we have observed that the color season of a person cannot be ascertained through crisp reasoning when the combination of body colors did not conform to any of the color season charts. Our probabilistic reasoning scheme yields a probability distribution over some possible color seasons in such cases.

Further, the annotations for the apparel are often incomplete and some of the semantic attributes used in the reasoning model may be unavailable. For example, the information about garment craft or material have not been available, or have some unknown value (with respect to the domain knowledge) for some of the Saris in our collection. While the crisp reasoning model fails to reason with such garments, our abductive reasoning model evaluates the suitability of the garment based on other available parameters. Though absence of knowledge about a few garment attributes has some impact on the recommendation results, but it does not render reasoning impossible. This flexibility helps in coping up with heterogeneous catalogs from different vendors with incomplete domain knowledge.

VI. Conclusion

We have created a proof of concept for personalized fashion recommendation using a novel probabilistic multimedia ontology. The architecture can be extended to other domains of media-rich products, where selection is primarily guided by the aesthetics of the media contents. Most importantly, the framework can seamlessly integrate content based and collaborative filtering techniques, both of which are extremely important for personalized recommendation.

REFERENCES


