Prediction of Fashion Trends for Apparel Recommender Systems

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***Abstract*—Online shopping became natural for many people. Electronic commerce is thriving, mainly due to modern technologies dedicated to keeping customers interested. An example of such technology is apparel recommendation systems. Fashion consumers, who value professional style advice, usually have to make a cognitive effort to obtain knowledge about the latest fashion trends. The goal of this project was to find out whether or not it is possible to build an intelligent system that can predict fashion trends automatically. Incorporation of such a system into apparel recommendation tools would benefit online shoppers as well as fashion retail companies. A trendy outfit is defined, among other things, by color and texture of the garment's fabric as well as dress line and shape. A thorough search in computer engineering databases revealed that currently no significant work had been done by computer scientists or engineers to forecast fashion trends related to fabric texture or dress cut. As for the color prediction, several machine learning techniques exist. Those techniques are based mainly on statistical models, Grey system theory, and artificial neural networks. The author of this research succeeded to detect one work that experiments with integrating knowledge about fashion color into an apparel recommender system.**

Keywords—recommendation system, apparel recommender, apparel, attire, clothes, fashion, fashion trend, style, color prediction.

I. Introduction

When it comes to shopping, more and more people turn to merchants that provide an online service. A person can shop at their favorite online store from any location at any moment. There is no need to spend time and energy to get to the store and make purchase decisions under restrictions of a particular location's open-hours and stock. However, an online shopper has to deal with other inconveniences. First of all, an abundance of available items complicates the decision-making process. Second, an online shop lacks the marketing advantage of a physical shop – visual merchandising. As a result, a customer gets overwhelmed by the choice possibilities. A decision to make a purchase might take much more time than it is acceptable and cause frustration for a customer.

Nowadays, to be competitive, an online retail shop has to utilize more or less sophisticated Recommendation System (RS). An RS is a software tool whose general purpose is to help a customer to navigate through an abundance of available items.

A particular case of a recommendation system is an apparel recommender system. Many apparel merchants recognize the importance of a personalized recommendation coupled with professional stylist advice. In fact, as for 2016, 14 out of 21 existing apparel recommender systems, use human agents to provide a customer with expert advice [1]. A professional stylist is aware of the latest fashion trends and can suggest a garment that is of a modern style, color, texture, and is appropriate for the occasion.

However, it is not feasible to provide human agent feedback as fast as an automatic machine-generated suggestion.
Another problem is that the service of a professional stylist is expensive, therefore not profitable for large e-commerce companies. Also, the customer may doubt a human agent's opinion, suspecting a stylist's agenda in promoting sales, not to mention that human stylist's preferences might be affected by his or her level of expertise and personal taste. Consequently, for both, customer and online retailer, it might be a good idea to employ a software tool that is trained to distinguish between trendy and out of fashion garments as well as to predict what kind of garment features are going to be fashionable in the next season.

This work is an investigation about the possibility of designing an intelligent software tool that can forecast fashion trends in clothing. The author researched publications in Computer Engineering domain to find existing solutions for fashion trends prediction. The study revealed that the research in artificial intelligence field concerned mainly in color trend prediction.

The apparent reason for computer scientists and engineers' interest in a fashion color trend prediction is that currently, this task is performed every year by human experts [2], [3]. Naturally, the interest exists among researchers to try and automate the process.

The organization of this paper as follows:

- Section II discusses the marketing advantages that a recommendation system can bring to a merchant. Also, Section II briefly explains the present technologies behind recommendations.
- Section III talks about specifics of an apparel recommender systems, justifies the need for fashion trends forecast in general and color trend prediction in particular.
- Section IV explains the methodology behind the literature review in this work.

- Section V provides an overview of technical solutions for an automatic color trend prediction.
- Section VI concludes this paper, talks about research limitations, and offers a possible direction for future work.

II. Background on Recommendation Systems

A. Goals of Recommendation Systems

In the past decades, scientific interest in recommendation systems has grown significantly. D. H. Park et al. [4] examined 210 papers from 2001 to 2010 about the research dedicated to recommendation systems. They discovered that 60% of the articles were published in the last three years of this decade, from 2008 to 2010, with 20% of the research dedicated to shopping applications.

Indeed, a capable recommendation system can bring to an online merchant many advantages [5]. First of all, a sound RS rises companies sales. By providing quality recommendations, an RS keeps a user engaged in surfing the website. From a customer perspective, the process might feel like an exploratory game. The user clicks on the suggested items that look interesting to him or her. In meanwhile, based on these clicks, the merchant collects statistics about the user's possible interests. This information is to generate further suggestions that might be more relevant. Ideally, the overall experience makes a customer satisfied and willing to come back for more purchases.

For a customer, to be subject for an intelligent system analysis brings many benefits as well. The main benefit is the fact that a good recommendation algorithm can save lots of time for an online shopper. The typical example would be a situation when a person needs some hardware tool, an electronic device, or a beauty product, but has no idea about the product's proper name or brand. In this case, an RS makes it possible to search an item, not by an exact name, but by a concept. An RS can draw similarities between a given user and other people's profiles based on previous purchases. With the provided concept and the additional information about the reviews for each product, an RS can generate an appropriate suggestion. As a result, a customer will, potentially, find the right item that satisfies his or her needs without a need to spend too much time and effort. Also, a comparison between different customers may result in a suggestion of a completely new item, not searched by a user. Many perceive this feature as an advantage similar to a recommendation that a person can get from a close friend.

A recommendation system's task is to help user sift through the data and *filter* items that will most likely fit his or her taste. The next subsection gives a brief overview of recommendation types from an algorithmic perspective.

B. Types of Recommendation

In terms of technology, several types of recommendation systems exist [5]:

1) Content-Based Filtering

The content-based recommendation suggests items based on users profile, feedback, and previous purchases. This approach can satisfy a unique taste, but there is a drawback to it. The recommendations may end up very similar to each other, leaving the customer bored and disengaged.

2) Collaborative Filtering

The most popular one [6], a collaborative filtering type of recommendation, aims to overcome the "overpersonalization" problem [4] of content-based recommendations. This type of RS draws suggestion ideas based on a similarity between active users. The collaborative filtering approach usually manifests itself by telling the customer: "People who bought *this* also bought *this*."

3) Demographics-Based Suggestions

The demographics-based recommendation generates suggestions based on the demographic profile of a user: geographic location, language, age, etcetera.

4) Knowledge-Based Suggestions

The knowledge-based recommendation system has initial data embedded in it. This data represents an expert knowledge of some kind. The knowledge-based recommendation can be case-based, constraint-based, or community-based.

In the case of an apparel recommender system, it is not enough to help user rummage efficiently through lots of available items on a website. Section III section talks about specific challenges that stand before developers of apparel recommender systems.

III. Apparel Recommender Systems

A. Specifics of an Apparel Recommender Systems

The experience of many apparel merchants [1] suggests that an expert apparel recommender should be able to provide a customer with personalized style advice. An intelligent apparel RS should possess expert knowledge about style, rules of color theory, and, most importantly, about current fashion trends. Also, when it comes to style advice, people rely on friends and relatives recommendation. This situation especially holds for those, who do not have time or interest to draw knowledge about modern trends from fashion magazines. The recognition of this fact motivated G. Sun et al. [7] to propose a system that makes clothing recommendations based on the user's social connections.

The work of D. Vogiatzis et al. [8] makes a step in the direction of the style-aware apparel recommender system. The researchers proposed a system that combines embedded style and fashion expert knowledge with "community-based style advice." Their system takes information about a customer as an input. The information may include body and face type, personal preferences for color, material and dress shape, or requirements for a garment to fit a special occasion or season. Based on this information, the system generates a generic suggestion. Then, the actual recommendation can be constructed, based on choices of a *community* of similar users.

The next step should be an incorporation of knowledge about modern fashion trends into an apparel recommender

system. T. Iwata et al. [9] approached this idea by proposing an apparel RS that suggests matching garments based on the information retrieved from the analysis of pictures in fashion magazines. In their work, T. Iwata et al. only relied on the color aspect of a garment to generate an appropriate suggestion. However, color alone does not provide enough information to give high-quality style advice.

For a recommendation system, to generate a high-quality outfit suggestion, other features besides color should be taken into consideration as well: textile weave and composition, fabric sheer and gloss, dress cut, decorative details, and etcetera. All these features contribute to the final look and feel of a garment. For example, a textile weave can be woven, twill, or knit, to name a few. The material composition can include cotton, wool, silk, polyester, leather, rayon, lyocell, and many more.

When it comes to fashion, the ultimate essential feature of a garment is, of course, a shape. For a human, especially a fashion guru, one look at the black-and-white photograph of an outfit is enough to determine a period in history the picture belongs. That is the reason an ideal apparel recommender should be able to recognize features of a dress shape: skirt or pants length, sleeve form, collar shape, fit (slim, relaxed, oversized) and many others. The assumption might be that a customer would prefer only a modern dress shape. However, if an RS would be able to recognize dress shape features, it would be possible for a user to request styles form different fashion epochs.

In addition to the ability of an apparel recommender system to recognize dress features, another useful function is to predict future fashion trends in general and color trend in particular. Color is an essential characteristic of any fashion piece of clothes, an accessory, or a piece of interior. An accurate color trend forecast is vital for many involved parties from textile manufacturers to fashion designers and consumers [2]. The following subsection provides a brief overview of the color prediction industry.

B. Color Trend Prediction Industry

Fashion color trend prediction is an international business. In 1953, the *Japan Fashion Color Association* was founded [10]. *Pantone Color Institute* that exists form 1962 is a US-based corporation [11]. In 1963, *Intercolor*, "an international and interdisciplinary platform of colour experts," was created by Japan, France, and Switzerland. Currently, it unites seventeen countries in Europe, America, and Asia [12]. All these organizations employ professional stylist, colorists, and fashion experts whose task is to predict the next color trend.

Fashion industry experts gather information about color trends in previous years and analyze them. Then, they predict the possible future color trend. The process is creative, non-deterministic, and highly dependent on the professional's level of expertise [3]. For example, in 2019 *Pantone Color Institute*, declared "Living Coral" to be color of the year. Nevertheless, in 2019, not many fashion designers used this color in their collections.

In this work, the author conducted the literature review on the recent technology advances that researchers have made in the field of color trend prediction. The next section explains the literature review method.

IV. Literature Review Method

The task of making a prediction based on the historical data analysis fits perfectly into the artificial intelligence and machine learning domains. Thus, the focus of this research is on the works that utilize machine learning techniques to make a fashion color trend forecast. The following databases were searched to retrieve existing publications:

Engineering Village

IEEE Xplore

Science Direct

Google Scholar

The keywords for the search are organized into five logic sets by topic.

1) The first set is for style and clothing terms:

*R_fashion = (fashion** OR *attire* OR *cloth** OR *apparel* OR *garment** OR *dress** OR *styl**)

2) The second set is for recommendation systems:

*R_recommend = (recommend** OR *suggest** OR *advice)*

3) The third set is for machine learning technology:

R_ml = ((intelligent OR *expert)* AND *system* OR *"artificial intelligence"* OR *AI)*

4) The fourth set is for fashion and color trends:

*R_ trend = (trend** OR *color** OR *colour** OR *hue**)

5) The fifth set is for prediction topic:

*R_predict = (predict** OR *forecast** OR *future)*

The asterisk * means "search for all possible spellings." The operators AND, OR are Boolean logic operators. Two variations of a search string are constructed as follows:

1) *R_fashion* AND *R_recommend* AND *R_ml*

This string is to search for articles related to apparel recommendation systems.

2) *R_fashion* AND *R_ trend* AND *R_predict* AND *R_ml*

This string is to search for articles related to color trend prediction technologies.

Only peer-reviewed articles were selected for analysis from the search results. Three of them explicitly deal with color trend prediction techniques [3], [13], [14]. Section V summarizes of the technology behind the color trend prediction presented in these three articles.

V. Technical Aspects of Color Trend Prediction

The color prediction techniques presented in the related literature can be conditionally classified in two groups. One group is statistical learning methods such as Bayesian Network and Auto-Regressive Integrated Moving Average.

Another group is machine learning methods such as Artificial Neural Network, Grey Model, Fuzzy System. This section gives an overview of those methods along with their performance.

A. Statistical Learning

Bayesian Network

Bayesian Network is a probabilistic model which represented mathematically as a directed acyclic graph – nodes connected with unidirectional arrows. Acyclic means that for any node it is impossible to start at the node and get back to it after passing several others. Each node in the graph is a random variable. Each arrow represents a conditional probability between the nodes it connects.

In 2017, P. Mello et al. [3] published a paper where they described an attempt to build a knowledge-based system for fashion color trend prediction. A collection of historical proposals made by human professionals was analyzed to provide the necessary initial knowledge for the system. Features in the form of words/ concepts and representative pictures were extracted from the available data and used to train Bayesian Network as a statistical model. Stylist examined the resulted color predictions and found them "very interesting." The stylist admitted that her own choices would be consistent with the system predictions.

Y. Yu et al. [13] systematically studied ARIMA, ANN, and a few variations of the Gray method. They conducted a study on the historical data from six years of autumn-winter men's fashion color trend. The goal of the research was to test the performance of the models on the prediction of fashion color hue and tone separately.

The performance evaluation metric for all methods is the S*um of Absolute Error*s *(SAE)*. The authors argue that color trend is "highly volatile" and more extended periods of historical data might be "inadequate." For that reason, Grey Method have a higher chance of an accurate forecast.

Auto-Regressive Integrated Moving Average (ARIMA)

ARIMA is a method used frequently in statistics in time series analysis. Since the color trend varies with time, it can be treated as time series [13]. ARIMA model has three parameters that should be set at the beginning:

p – lag order, number of time lags in the autoregressive model

d – differencing degree

q – order of moving average, number of terms in a moving average

As the authors assert, only two options for the ARIMA model's settable parameters are relevant:

$(p, d, q) = (1, 0, 0)$

$(p, d, q) = (0, 0, 1)$

B. Machine Learning Methods

Artificial Neural Network (ANN)

ANN is an abstract mathematical structure which consists of nodes and arrows that connect them. The nodes in the network arranged in layers. The first layer is called an input layer, whereas the last layer is an output layer. The layers in between are hidden layers. Each node represents a value, and each arrow represents a weight. The value of a node in a given layer is a weighted sum of the nodes in the previous layer. The flexibility of the model depends on the number of nodes in the hidden layers. Thus, the decision about the number of nodes is a crucial one.

Let N be the number of nodes in the hidden layers of ANN. The optimal value for this parameter is determined by trying out several options and choosing the one with the lowest forecasting error. In Y. Yu et al. [13] work, the final choices of N are as follows:

$N = 3$ for color hue prediction model

$N = 2$ for color tone prediction model

The following three methods, GM, GNNM, and GRA-ELM are from the Grey System Theory that developed from the necessity to deal with the cases where not enough information is available.

Grey Model (GM)

GM is the differential equations model with two parameters:

M – the order of each differential equation

N – the number of variables

The following two options were tested:

$(M, N) = (1, 1)$

$(M, N) = (2, 1)$

The reason for the above choice of parameters is that the higher degree of differentiation may result in more significant inaccuracies [13].

Grey Neural Network Model (GNNM)

GNNM is a combination of ANN and GM. In GNNM, an ANN is used to determine the best parameters for GM and improve accuracy [13].

Extreme Learning Machine (EML) with Grey Relational Analysis (GRA)

EML is an expedited version of ANN. The problem with ANN is that it takes too much time to determine the best values for the model by "learning." Whereas in EML, the optimal values are determined analytically, which is faster. GRA is a method from the Grey System Theory that aims to outperform regression analysis in the situations where information is not sufficient – uncertain, incomplete.

Table 1 summarizes the findings presented in Y. Yu et al. [13]. The results show that the GRA-EML, a hybrid method proposed by the authors, performs better than other methods on color tone prediction, whereas ANN yields the best result for color hue forecast. However, the ANN model is slow compared to GRA-EML: minute versus seconds. Thus, the GRA-EML method is, arguably, the best among the presented.

Fuzzy System

A fuzzy system is the one based on fuzzy logic. In Boolean logic, the variables can accept only values 0 or 1, while in fuzzy logic the variables can be in-between.

Table 1
Sums of Absolute Errors for various color prediction methods presented in Y.Yu et al. [13].

	ARIMA	*ANN*	*GM*	*GNNM*	*GRA-EL M*
hue	*15.07*	***11.47***	*18.43*	*21.97*	*12.89*
tone	*16.08*	*17.59*	*16.31*	*36.62*	***14.81***

C. L. Hui et al. [14] proposed a fuzzy system to predict a color trend that can fit the requirements of a specific cultural group. The researchers developed "preliminary knowledge" about possible color preferences and integrated them into a fuzzy system. Since different cultures perceive colors differently, it is essential to make use of predefined preferences to get better prediction accuracy. The authors focus their research on Chinese culture. The most significant factors that contribute to specific color preference, as determined by the researchers, are age, gender, height, skin color, emotional state, social status, fashion, and personal habits.

To evaluate the performance of the proposed system, C. L. Hui et al. [14] cooperated with five apparel designers. The designers represented the "preliminary knowledge" about a hypothetical target group in terms of six factors. After generating a color proposal, the researchers surveyed 100 people as the "target customers." On average, 85% of the respondents rated the proposed color as "strongly like."

VI. Conclusion

This work is a literature review on the topic of fashion color trend prediction. Initially, the goal of this project was to find out whether or not it is possible to build an intelligent system that can predict future fashion trends, mainly related to a personal style and attire. If the prediction is not possible, then whether or not we can, at least, build a system that can distinguish between trendy garments and out of fashion ones. In the author's opinion, the online apparel retail companies might benefit tremendously from an intelligent system of this sort.

The research revealed that currently no attempts were made by computer scientists to develop an intelligent system to predict a trend for personal style attributes. On the other hand, several recent works exist, that investigate the possibility of an automatic fashion color trend forecast even though that some researchers [15] doubt the existence of any explicit or subtle rules that bring to the emergence of the color trends in fashion. The existing color prediction techniques make use of statistical models, such as ARIMA and Bayesian Network, as well as machine learning approaches, such as ANN, Grey Model, Fuzzy System.

It is essential to mention all the limitations of the work presented here. First, the resources were restricted only to free access publications. Also, the author could only review the English language papers. The latter is unfortunate since several promising publications were found in Japanese. In fact, according to L. X. Chang et al. [2], Japan made a great effort in research dedicated to fashion color prediction using data mining and machine learning techniques.

Another limitation was the requirement to reference only peer-reviewed papers. While the author understands that peer-reviewed articles are the most reliable source of information in an academic world, not peer-reviewed conference papers constitute a higher percentage of the total number of publications, and, consequently, provide a better insight into a present state of research.

In the future, the author would like to see more research that aims to find a solution to the problem of automatic fashion and style advice.

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