Big Data in Fashion Industry: Color Cycle Mining from Runway Data

Full Papers

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Abstract

Color is a powerful selling tool, especially in the fashion and textile industry, in which products aim to inspire consumers visually. Color Cycle Analysis studies the recurring cycle of trends. Traditional fashion color cycle analysis and prediction is performed by observing and extrapolating from trends apparent on fashion runways. With the emergence of big data, there is a potential to apply data analytics method in fashion industry. We propose and develop a data-driven methodology to analyze color trends by mining online textual data of global fashion runways collected from the Style.com website. By capturing three important elements in color hue, saturation and brightness, we are able effectively extract their presence and variations in textual data. We illustrate the reoccurrence of seven Color Cycle phases: High Chroma, Multicolored, Subdued, Earth Tones, Achromatic, and Purple Phase from runway review data.

Keywords

fashion analytics, Color Cycle Analysis, text mining, knowledge base

Introduction

As businesses stockpile more and more data in this digital age, business intelligence methodologies and analytics are increasingly utilized to make sense of and exploit patterns and trends in the data. An industry in which trends are notoriously difficult to predict is fashion. Any successful fashion trend identification (and prediction) could nevertheless yield great commercial dividends for clothing retailers, as well as designers and other industry stakeholders.

One element of fashion that seems especially ripe (perhaps deceptively so) for quantitative trend analysis is color. Color is a powerful selling tool, especially in the fashion and textile industry, in which products aim to inspire consumers visually. As the International Color Authority says: "Color comes before style and price, and is the first factor to which the customer responds" (Scully, 2012). Color trends are often thought to occur in cycles, which manifest not only as "the periodic shifts in color preferences" but also as "the pattern of repetition in the popularity of colors." (Brannon and Divita, 2015) Such cycles can "land" on individual colors or even entire palettes of colors. Accordingly, many fashion companies especially fast-fashion companies (fashion retailers that try to quickly capitalize on the latest fashion trends) invest in forecasting services (internally and externally) to gain foresight into the zeitgeist of future seasons. Understanding fashion trends (current and future) will not only guide designers, product developers, and retailers in making profitable decisions, it will also inspire their creativity by connecting them to their customers and the spirit of the time.

Traditional fashion color cycle analysis and prediction is performed by observing and extrapolating from trends apparent on fashion runways. Widespread internet access, search tools, and digital content have democratized access to huge amounts of fashion information, and the increasing speed of digital information today has sped up the fashion trend cycle. Accordingly, a fast and efficient way of

summarizing fashion runway trends comprehensively is needed. Herein, we propose and develop a data-driven methodology to analyze online textual data of global fashion runways collected from the Style.com website. Our proposed method relies on (1) creating a knowledge base that capturing three important elements in color hue, saturation and brightness, (2) effectively mapping each color group and their variations in textual data, and (3) performing analysis on runway review data to observe color cycle and color trends. Our methodology is a pioneer study that provide a direction to combine the trend of big data analytics with quantitative reports on color trends from the years 2000-2016.

The rest of the paper is organized as follows. We first describe the key elements of color used in this study; Fashion Color Cycle, Disruption in fashion trends, Color Systems and their respective contributions. We then give a brief overview of the various methods used in the fashion industry to generate a color trend report. Next, we propose an innovative text mining method on runway review data to capture color trends. Finally, we present the preliminary results along with validations.

Related Work

Fashion Color Cycle Theory

Color cycles are theorized to occur as two types of phenomena: the shift in color preferences and the repetitive patterns in color popularity. These phenomena may occur because consumers lose their excitement for the current trend and seek novelty. Hence, fashion may owe to the psychological mechanism of boredom for these phenomena (Brannon and Divita, 2015). Consequently, it is possible that color trends can be forecast through a predictable cycle (Jack and Schiffer, 1948) and that previous popular colors can be repositioned in the future (Moschopoulos and Dahlstrom, 1999). Researchers have observed and theorized that periodic shifts proceed from high chroma colors, to "multicoloredness," to subdued colors, to earth tones, to achromatic colors, and lastly to purple phase, before cycling back to high chroma (Brannon and Divita, 2015). This cycle is illustrated in Figure 1. A full color cycle was observed in recent decades; from 1972 (high chroma) – 1992 (purple phase), swinging back to high chroma in 1998 (Brannon and Divita, 2015; Barry, 1999). Thus, the last full cycle took 26 years to complete. However, the shift in color preference in the 21st century was theorized to have accelerated, fueled by fast fashion (Scully, 2012; Bruce and Daly, 2006) and the internet. "Trends now have an average lifespan of just eight to 12 weeks, instead of five months two years ago", said Philip Kowalcyzk, director of retail services at the management consulting firm Kurt Salmon Associates (The Tuscaloosa News, 2/26/2001).

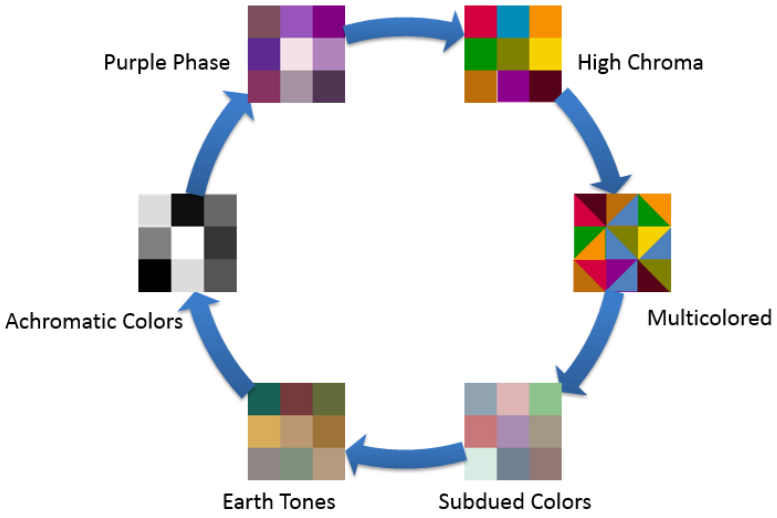

Figure 1. An illustration of long-wave color cycle

Major political, sociological and economic events can cause color preferences to the shift more rapidly than normal. The global stock market crash of 1987 ended the materialistic values of the economic boom era, along with the image of wealth and success expressed through fashion. Bright and vivid (high chroma) colors that defined the palette of the 1980s were replaced by a minimalist palette of neutrals or achromatic colors; black, beige, and gray (Scully, 2012). However, there lacks empirical study that validates the disruption hypothesis. Thus, we will inspect the color trends during The Great Recession that began in 2008 for a similar shift in palette.

Color Trend Analysis in Fashion Industry

Traditionally color trend reports have been primarily qualitative exercises. Scully (2012) summarizes traditional qualitative methods of generating color trend reports as shown in Table 1. In 1992, Buddy (1992) outlined a purely qualitative review of color trends from the 20s through the 80s, and speculated on the emergent trends of the 90s. As she describes, the primary methods of color trend market research: "reading magazines…seeing films…watching television…taking notice of people…looking at and into shops…etc." All of these methods are obviously purely qualitative. The last 25 years has a steady increase in research into quantitative fashion color forecasting. For instance, as early as 2 years later, Dransfield (1994) demonstrated that the forecasting software Logol could be used effectively to forecast fashion color demand and its implication on the entire supply chain of a textile company. Chang et al (2009) draw the clear distinction between color forecasting based on a "systematic methodology" (such as qualitative analysis by authoritative color forecasting associations based on connected factors like "vogue, social lifestyle, global economy, customers' color preferences, military affairs and so on", as described further in (Delong and Martinson, 2012; Briggs-Goode and Townsend, 2011; Li et al., 2011) and "historical data analysis methodology" (the now-emerging quantitative analyses). Several of the most prevalent quantitative color forecasting methodologies included the comparison method, statistical analysis methods, rough set theory (Chang et al., 2009), and grey system theory (Chang et al., 2009, Jin et al., 2010, Wu and Sun 2011, Choi et al., 2012). Table 1 highlights the emergence of quantitative methods and sources of color trend reports.

Method	**Description from Literature**	**Example of sources**
Qualitative Analysis		
Recording observations	Compile notes of observations with words and tactile collectible items	Photographs, sketches, yarns, ribbons, postcards, and fabric swatches
Studying Designer Collections	Interpret fashion color and trend direction by studying designer collections to inspire and confirm forecasted color palette	Magazines, video reports and fashion runways
Observing other industries	Observe and extrapolate events and products that touch the lives of consumers	Music, sports, advertising, foods, finance and politics
Joining Professional Organizations	Participate with organized color councils to network and confirm observations	British Textile Colour Group (BTCG), Intercolor, or Color Marketing Group
Quantitative Analysis		
Market Data and Analysis	Subscribe to fashion forecasting organizations that produce market projection using data quantitative and qualitative measurements garnered through market research, consumer group surveys and street questionnaires	Retail Forward, NPD Fashionworld, Mintel, WGSN, Just-Style, View Network

Table 1. Traditional methods of generating color trend reports

Research Gaps

Although quantitative methods have shown to be promising, existing studies have several challenges. *First*, color trend and color cycle is a complicated phenomenon that can be affected by many factors, such as the fast spreading of information on the Internet, the economy recession, celebrity influence, etc. Existing quantitative models based on historical data failed to take these factors into consideration. *Secondly*, many of the prior methods were based on analyzing historical fashion color data--often graphical--using the Munsell color space (color value, hue and saturation) apparent in the data. The result cannot be directly translated to color text. There are over three hundred ways to describe pink. Thus, buyers will pick similar color by visual comparison. Textual description of color has not been studied in previous color trend analysis research. *Thirdly*, most studies are based on data published in market report. However, these reports were composed from manual qualitative analysis and are prone to error and are limited in scope. *Lastly*, there has been few empirical validation of color trend analysis and forecasting studies.

Research Design

Our method herein is somewhat unique in that it analyzes textual fashion data (from the Style.com archives), and instead of the Munsell color system, we implemented the HSV (Hue Saturation Value) color space to categorize colors cited in text in coherent groups (such as "High Chroma," "Subdued Colors," "Achromatic" and "Purple Phase"). Additionally, we supplemented our textual knowledge base with "synonym text" (short words that describe a categorical set of colors, such as "muted palette") and "modified text" (general modifiers that describe a single color, such as "soft" pink). These novel elements of our work helped us go beyond the prior work by distilling some aspects of the artistic moods of the apparent fashion color trends.

We use quantitative methods to generate the color categories in Figure 1, in order to enable the color cycle analysis. In addition, we observe the duration of the full color cycle and each color phase to investigate whether elite fashion runways are also affected by this new speed in trends.

HSV Color Systems

The color forecaster is the first link in establishing and communicating color direction and color standards for apparel and fashion-related products. Perception and understanding of color are subjective, hence it is critical that we use a standardized language when describing color. The color forecaster is the first link in establishing and communicating color direction and color standards for apparel and fashion-related products. Perception and understanding of color are subjective, hence it is critical that we use a standardized language when describing color. In colorimetry, the Munsell color system is one of the earliest and most common system used to describe color, using hue, value (lightness), and saturation (color purity) (Joblove and Greenberg, 1978). However, we found the newer HSV system (widely adopted in image processing) more convenient for conversions between RGB (red/green/blue) color encoding and the same basic qualities as the Munsell system: hue, value and saturation (Li and Guo, 2010). These conversions were necessary to enable our systematic categorization of the colors. These interrelated HSV qualities are shown in Figure 2, arranged in a cone color space (Cardani, 2001).

Hue. Hue is a quality used to distinguish one color from another. Most viewers will first notice the hue before its other characteristics (Cardani, 2001).The primary and secondary hues in the HSV system (red, yellow, green, cyan, blue and magenta) comprise the circular face of the HSV color space cone. Encoded as integers, hue ranges from 0-360, beginning with red. ***Value.*** Value is a quality that describes the brightness of a color. Encoded as integers, value ranges from 0-255, with 0 being the darkest and 255 being the brightest. Brightness increases moving vertically towards the top of the HSV color space cone (Cardani, 2001). ***Saturation.*** The quality saturation represents the "purity" or saturation of a color. Less saturated colors (which are lesser in "purity") appear to be washed out, like pastel colors, or appear to contain some element of grayness. More saturated colors, on the other hand, appear vivid and striking. Encoded as integers, saturation ranges from 0-255. Saturation is represented as the distance from the center of the cone (Cardani, 2001) as illustrated in Figure 2.

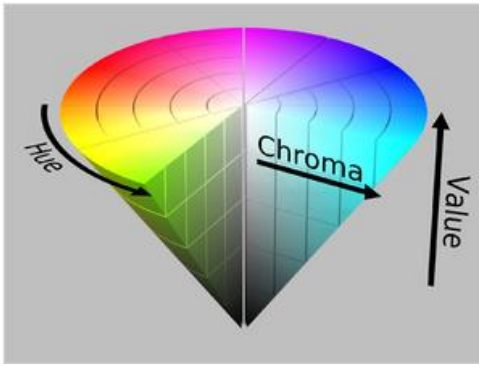

Figure 2. HSV cone color space (SharkD, 2016)

Color Knowledge Base: Mapping Text to HSV Color System

To map text-based color names to HSV color system, a color lexicon was generated, consisting of color names, their corresponding HEX codes, and RGB values, collected from multiple online sources (Pantone 2016; ColorHexa, 2016). Three types of text types were then established.

Using the HSV color system, the color space defined by saturation (color purity) and value (lightness) were established by manipulating the collected RGB values. We produced 2 new calculated fields, *S* and *V*, the color's corresponding saturation and value (hue, which is also part of the Munsell color system, will be used in a separate analysis). First, the RGB values are pre-processed (RapidTables, 2016) to produce *Cmax*, *Cmin* and Δ:

$$R' = R/255$$
$$G' = G/255$$
$$B' = B/255$$
$$Cmax = \max(R', G', B')$$
$$Cmin = \min(R', G', B')$$
$$\Delta = Cmax - Cmin$$

Next, formulas (RapidTable, 2016) are applied to the *Cmax*, *Cmin* and Δ to yield S and V (Equations 1 & 2):

$$S = \begin{cases} 0 & , C_{max} = 0 \\ \frac{\Delta}{C_{max}} & , C_{max} \neq 0 \end{cases} \quad (1)$$

$$V = Cmax \quad (2)$$

Additional formulas were applied to create a range that captured colors that were within the "High Chroma," "Subdued Colors," "Achromatic," and "Purple Phase" categories. The steps are described below.

1. For the "High Chroma" category, we selected colors with *S* in the top 90th percentile.
2. "Subdued Colors": we selected pastel colors that are in the bottom 50th percentile in *S* and the top 78th percentile in *V*. We also added muted colors (those with high gray content) into the "Subdued Colors" category. Colors with little or no distance between R, G, and B contain very little or no hue, making them white, grey or black. Hence, for the "Subdued Colors" category, we selected muted colors that comprise the bottom 90th percentile in *S* and top 50th percentile in *V* and have a 5-40 variance between R, G and B.
3. Colors with 0-2 variance between R, G and B show no visible hue, and thereby comprised the "Achromatic Colors" category.

4. "Purple Phase": purple hues were selected by filtering for colors in which red (R) and blue (B) content were higher than green (G), and limiting the differences between the blue (B) and red (R) content in the color to be less than 50.

Colors names were placed in their respective categories. Table 2 shows a sample of "High Chroma" category. Two additional steps are applied to improve the mapping coverage: adding synonym text and modified text.

Color Name	HEX	R	G	B	Saturation HSV	Saturation HSL	Value(H)
lemon	#fff700	255	247	-	100	100	255
aqua	#00ffff	-	255	255	100	100	255
azure	#007fff	-	127	255	100	100	255
safety orange	#ff6700	255	103	-	100	100	255
scarlet	B52C45	244	69	24	90	91	244

Table 2. Sample of color knowledge base dimensions (High Chroma)

Synonym text are short words that describe a set of colors belonging to a category. In the Style.com dataset, these words describe the set of colors seen on the runway. For example, in a 2003 Style.com article: "Branquinho delivered on all her signature looks: leggings worn with knee-high boots, V-neck cocktail slips, tweedy knee-length skirts, woven crisscross straps and a mostly muted palette." Here "muted palette" describes the set of colors used in the designer's collection for the season. To generate the synonym text, a set of adjectives and nouns were compiled and paired. The relevant set of adjectives are those that are synonymous with the name of the 6 collected categories. For example, here "muted" is synonymous with "Subdued Colors." Next, each adjective is paired with 5 nouns ("palette", "hue", "color", "shade" and "tone") to produce search terms such as "muted palette", "muted hue" and "muted color." Similarly, other sub-color categories that fall under these 6 categories were collected. Example: "color-block" for "Multi-Colored" and "pastel" for "Subdued."

Modified text are general terms used to describe a single color, such as "light blue", "vivid green" and "soft pink". First, 32 adjectives such as "deep", "pale" and "light" were collected. Then, in the Style.com dataset, nouns appearing after these adjectives were collected. Next, only nouns that exist as color names in our knowledge base are kept**.** The nouns are then paired with these adjectives with both " " and "-" as separators. Modified text such as "pale pink" and "deep-blue" are generated and added to the knowledge base.

An additional ad-hoc category, "Neutral," consisting of 7 neutral colors and 1 synonym text ("neutral") was added to the knowledge base to study the changes in color trends during the start of the economic recession in 2008. After the knowledge base was established, we cleansed it of text that created noise by removing color names with multiple definitions and general color names. Color names with multiple definition like "rose", "pearl" and "angora" were manually cross-checked with Style.com dataset for meaning in context, then removed when found to be used for other definitions. Next, conflicting general & primary color names were removed. For example: "blue," which was categorized as "High Chroma" in our knowledge base, could also belong in other categories, depending on its context in Style.com, hence will return incorrect count.

Data Source: Style.com

Instead of relying on fashion market reports, we use a fashion runway review dataset extracted from Style.com, formerly an online site for Vogue, the world's most influential fashion magazine. It contains extensive galleries and reviews of top designers' collections, written by experts in the industry. The

reviews are descriptive and typically do not contain excessive subjective opinions, but rather typically describe inspirations for design, such as silhouettes, shapes, colors, fabrics, specific details (Lin et al., 2014). Thus it offers a good source for data analytics.

We collected fashion reviews from Spring 2000 to Spring 2016, which included reviews for 816 designers in 30 fashion seasons, represented in 7940 total reviews. It is important to note that the number of designers included in Style.com's review section has increased over the years, ranging from 97 designers in Spring 2000 to 459 designers in Fall 2014 (Lin et al., 2014). A brief summary of the dataset it shown in Table 3.

First season	Last season	# of reviews in 2000	# of reviews in 2015	Total seasons	Total reviews
Spring 2000	Spring 2016	193	877	33	7940

Table 3. Summary of Style.com fashion runway reviews dataset

Data Normalization

The Style.com dataset was parsed for frequency of each text collected in the knowledge base. Normalization was performed on 3 levels to address the issues with disproportionate distribution of text in each category, multiple hits for a single text within the same article, and the significant increase of available data over time (shown in Figure 3):

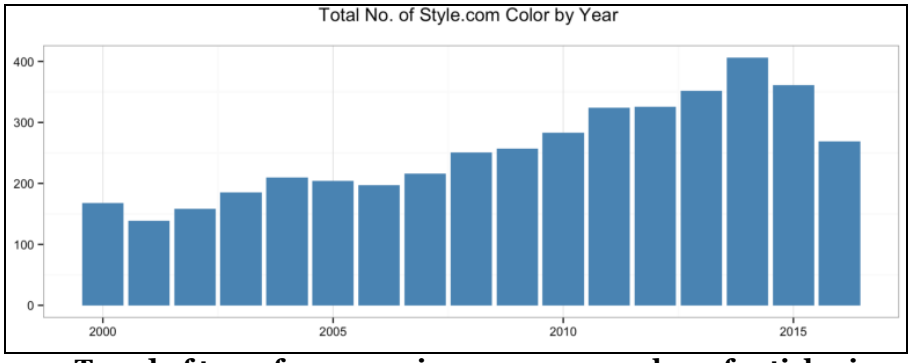

Figure 3. Trend of term frequency increases as number of articles increase

To address the first issue, the number search terms for each category was standardized by limiting the number of color names to the top 32 (by frequency) across all categories. As for modified text and synonym text, a methodological procedure was used in generating them, standardizing the number of adjectives and nouns collected to produce those texts. Then, the top 50 (based on parsed frequency) were retained, with the rest discarded. To address the second issue, multiple hits for a single text within an article were omitted. Some articles mention a specific word more frequently, but this article-specific frequency likely does not quantify the popularity of that color for that time period. Hence, only the first hit for a term is counted for each designer in each season of a year. To address the third issue, the individual parsed results are normalized by the total parsed results for that year.

Experiment with Runway Review Data

Color Cycle Analysis

Color Cycle Analysis studies the recurring cycle of trends. If we are able to identify a distinct cycle, we would be able to predict upcoming color trends. We start with allocating scores to each text collected in our knowledge base based on the frequency of the parsed text. Each frequency is scored based on the text type: each frequency for color and modified text counts for 1 point, while each frequency for synonym text counts for 5 points (because it refers to a palette of multiple colors). The score is then normalized and divided by the highest value for its category to produce a final score ranging from 0 to 1 across all categories. The final results are presented as a heatmap shown in Figure 4 to show the parsed results from Style.com fashion runway reviews, based on our knowledge base. Dark red indicates that there were high

frequency of text captured for that particular category indicating popularity of that color phase within that time period.

Phase	yr2000	yr2001	yr2002	yr2003	yr2004	yr2005	yr2006	yr2007	yr2008	yr2009	yr2010	yr2011	yr2012	yr2013	yr2014	yr2015	yr2016
High Chroma	0.87	0.53	0.5	0.91	0.8	1	0.5	0.73	0.71	0.62	0.63	0.89	0.75	0.71	0.61	0.78	0.69
Multicolored	0.72	1	0.45	0.31	0.45	0.47	0.34	0.38	0.82	0.66	0.71	0.66	0.84	0.64	0.48	0.8	0.64
Muted	0.76	0.55	0.73	0.83	0.85	0.76	0.67	0.52	0.77	0.69	0.83	0.63	0.67	0.55	0.65	0.72	1
Earth	0.52	0.45	0.82	1	0.82	0.91	0.54	0.68	0.64	0.54	0.54	0.44	0.48	0.44	0.49	0.34	0.47
Achromatic	0.55	0.64	0.75	0.58	0.44	0.59	0.67	0.68	0.65	0.7	0.6	0.79	0.76	1	0.81	0.7	0.68
Purple Phase	1	0.6	0.72	0.72	0.84	0.59	0.74	0.68	0.82	0.84	0.68	0.64	0.53	0.66	0.98	0.82	0.58
Neutral	0.58	0.75	0.88	0.81	0.77	0.77	1	0.92	0.74	0.81	0.83	0.82	0.75	0.76	0.8	0.75	0.76

Figure 4. Style.com fashion runway review color cycle trend results

There was no obvious color cycle sequence apparent in the Color Cycle Analysis results. In any case, the High Chroma➔Multicolored➔Subdued➔Earth Tones➔Achromatic➔Purple Phase sequence suggested in prior literature (Brannon and Divita, 2015) was not immediately apparent. There were, however, several interesting findings. For instance, no color palette remained at peak popularity for more than 2 years, seemingly confirming the fickle color tastes of fashion consumers. Additionally, no dominant color trend was apparent during the beginning of The Great Recession (starting in 2008). This result may be correlated with weakened purchasing power for luxuries during this period.

Pantone's Color of the Year

As shown in the Figure 5 results, there was some significant correlation (as expected) between a color being nominated as Pantone Color of the Year and its search term frequency peaking (especially during the period from 2009-2015). However, it should be noted that we typically observed the Color of the Year becoming a popular search term only as early as December of the previous year. This could be attributed to the release of the color on their website during that time of year.

Year	Pantone's Color of the Year	Search term	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
2015	marsala	marsala color	0	0	0	0	0	0	0	0	0	0	0	100
2014	radiant orchid	radiant orchid	0	0	0	0	0	0	0	0	0	0	100	76
2013	emerald	emerald color	0	0	47	29	33	31	42	36	95	100	59	63
2012	tangerine tango	tangerine tango	0	0	0	0	0	0	0	4	100	13	7	5
2011	honeysuckle	honeysuckle color	0	0	0	0	0	0	0	100	9	7	6	6
2010	turquoise	turquoise color	0	40	28	20	23	36	45	42	67	77	85	100
2009	mimosa	mimosa color	0	0	0	0	100	84	0	0	0	27	25	27
2008	blue iris	blue iris color	0	0	0	0	0	0	0	0	92	89	100	99
2007	chili pepper	chili pepper	70	46	100	64	40	38	32	46	41	32	33	31
2006	sand dollar	sand dollar color	0	0	0	0	0	0	0	0	0	0	100	0
2005	blue turquoise	blue turquoise	37	30	27	25	32	38	46	46	67	77	92	100
2004	tigerlily	tigerlily color	43	46	50	48	51	73	68	56	57	62	80	100

Figure 5. Pantone's Color of the Year search term popularity

Validation with Google Trend

Color cycle trend results were cross validated with results from Google Trends. Google Trends was referenced in order to help validate the accuracy of the model. However, the typical search terms reported in Google Trends are often nouns or specific objects, rather than the words that represent our knowledge base categories (which are mostly adjectives). Rather than only selecting nouns to represent spot-check our study validity, we combined adjectives with a noun of a fashion item to produce a more typical Google Trends search term representing our category. An example one such modified text is "Multicolor dress," which represents the "Multicolored" category. For example, the text "Color-block" which is readily available as a noun from our knowledge base's "Multicolored" category is plotted in comparison with the normalized "Colorblock" results from Google Trends as shown in Figure 6. We observed that both trends are similar, with the search term frequency peaking around the same 2012-13 time period. The Style.com fashion runway reviews, however, indicated "Color-Block: as a seasonal trend that came back strong in

2012, while Google Trends indicated a more sudden and isolated popularity starting in 2011 and peaking in 2013. This could be an indication of fashion runway colors creating excitement in mass market fashion.

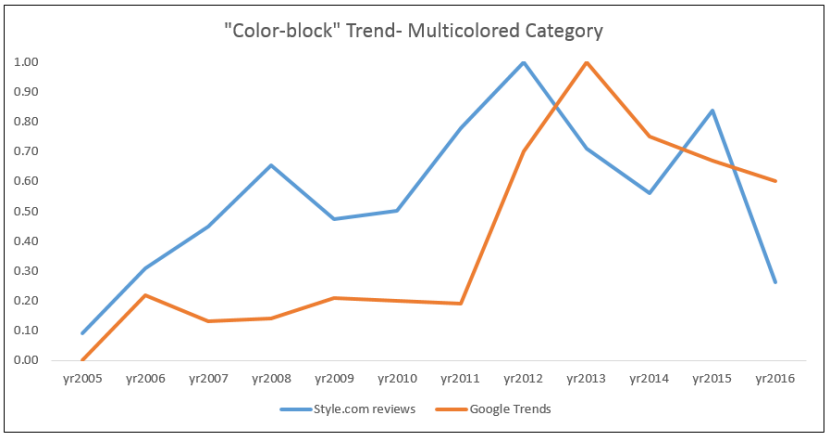

Figure 6. "Color-block" term frequency in Style.com reviews vs. Google Trends

Conclusions

In this project, we developed a quantitative method to group related colors, synonym text, and modified text by oft-cited palettes that reflect certain moods (such as "High Chroma," "Multicolored," Subdued," "Earth Tones," "Achromatic," and "Purple Phase). We develop a research method that maps groups of color to textual data and thus enables quantitative data analytics on large scale dataset. Using Style.com fashion runway reviews, we obtained term frequencies of the collected text in each category. A weighted scoring system and normalizations were applied to show the yearly popularity of each category. The term and category frequency results were then plotted as a heatmap to identify well-known long-term color cycles (or lack thereof, in this case).

We believe this study is a first step to enable big data analytics in fashion industry. Our research not only examine the correlation between the Style.com trends and color cycle movement, but also to highlight potential of the Style.com data to even occasionally forecast the nomination ahead of time.

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