

Finding Similar Clothes Based on Semantic Description for the Purpose of Fashion Recommender System

Dariusz Frejlichowski¹(✉), Piotr Czapiewski¹, and Radosław Hofman²

¹ Faculty of Computer Science and Information Technology,
West Pomeranian University of Technology, Zolnierska 49, 72-210 Szczecin, Poland
{dfrejlichowski,pczapiewski}@wi.zut.edu.pl

² FireFrog Media sp. z o.o., Jeleniogorska 16, 60-179 Poznań, Poland
radekh@fire-frog.pl

Abstract. The fashion domain has been one of the most growing areas of e-commerce, hence the issue of facilitating cloth searching in fashion-related websites becomes an important topic of research. The paper deals with measuring the similarity between items of clothing and between complete outfits, based on the semantic description prepared by users and experts according to a previously developed fashion ontology. Proposed approach deals with different types of attributes describing clothes and allows for calculating similarity between the whole outfits in a domain-aware manner. Exemplary results of experiments performed on real clothing datasets are presented.

Keywords: Clothes similarity · Object retrieval · Recommender systems

1 Introduction

Recently the fashion domain has been one of the most dynamically growing areas of e-commerce and social networking. Given the popularity of the topic, especially among women, number of potential customers is vast.

At the same time, buying clothes on-line poses a bigger problem, than in other areas of e-commerce. First, lack of physical contact with the merchandise is for many people a discouraging factor. Second, due to the great variety of clothing styles and certain difficulties in clearly and unambiguously describing them, it is quite difficult to search for desirable clothes. Furthermore, in real-life shopping for clothes it is quite common to ask for advice of a shopping assistant.

Due to the above factors, the analysis and representation of clothes became an important topic of research within several subareas of computer science, including computer vision, knowledge representation, information retrieval and recommender systems. The method presented in this paper is intended to be incorporated in the fashion recommender system being currently under development. The ultimate goal of the system is to learn the individual style of the user

(based on the outfits owned by them and on their clothing preferences expressed in other ways) and then to recommend some matching new clothes.

An important part of such system is comparing clothes in terms of fashion and visual characteristics. The proposed similarity measure aims at expressing the level of resemblance between two complete outfits (each consisting of any number of garments), and can be used in two basic usage scenarios:

- directly finding clothes similar to a given reference outfit;
- clustering outfits in order to recognize distinguishable styles.

The rest of the paper is organized as follows. Section 2 contains the review of relevant literature dealing with similar problems. Section 3 presents proposed method of representing clothing items and outfits. In Sect. 4 the proposed similarity measures is described, both for single clothing items and for complete outfits. Section 5 presents some experimental results. Section 6 concludes the paper.

2 Previous Works

Analysing various fashion-related data just recently became an active area of research. Most of the work has been done in the field of computer vision, focusing on analysing images containing clothes and outfits.

Zhang et al. [7] proposed a human-computer interaction system called a responsive mirror, intended to be used as an interactive tool supporting shopping in a real retail store. Cloth type and some attributes are automatically extracted from the image and similar clothes are looked for in a database. Di et al. [3] proposed a method to recognize clothes attributes from images, limiting the area of interest to one category of clothes (coats and jackets). A similarly limited approach can be found in [1], where only upper body clothes are analysed. The main focus in all the above research is on computer vision aspects and the semantic description of clothing is very limited. Also, none of the above deals with the whole outfits, only with single items of clothing.

The topic of similarity between items of clothing has been dealt with in [2, 6]. In [2] the issue of similarity is taken only from computer vision perspective, no semantic description of clothing is considered. In [6] authors propose a tabular structure to describe cloth characteristics and then propose a procedure to calculate the similarity. Their proposed structure lacks the flexibility that can be achieved using the fashion ontology described in the next section of this paper. Also, both above mentioned papers deal only with single elements of clothing, no means of analysing complete outfits is proposed.

General similarity measures intended for usage in retrieval tasks are discussed in [4, 5]. However they do not deal with domain-specific issues related to fashion datasets.

3 Semantic Description of Clothing

For the purpose of creating fashion recommender system, a lightweight fashion ontology has been developed. Then some clothing images have been collected and semantically annotated in accordance with the ontology.

3.1 Clothing Ontology

The four most important concepts of the developed fashion ontology are:

- cloth type (a class representing a type of clothing, e.g. trousers, shirt etc.);
- cloth attributes (describing a particular cloth item, e.g. sleeve length, collar type, colour etc.);
- cloth item (a single, particular instance of clothing, described by some attributes);
- cloth set (a complete outfit; a composition of clothes, intended to be worn together).

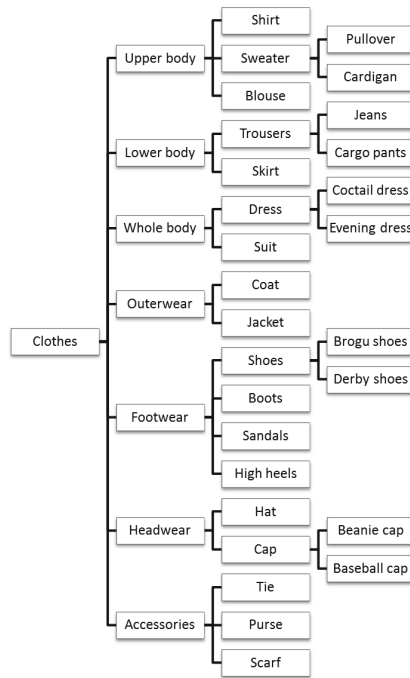


Fig. 1. Excerpt from the cloth type taxonomy defined within the fashion ontology.

A cloth type taxonomy has been defined (see Fig. 1), arranging all cloth types into a hierarchy, the first level of which corresponds to most general categories of clothing – 7 main categories were defined:

- upper body (e.g. shirt, sweater),
- lower body (e.g. jeans, skirt),
- whole body (e.g. dress, suit),
- footwear (e.g. boots, high-heels),
- headwear (e.g. hat, baseball cap),
- outerwear (e.g. coat, leather jacket),
- accessories (e.g. purse, tie, scarf).

Cloth attributes are defined on different levels – some are common to all cloth types (e.g. colour), some to only certain cloth categories (e.g. sleeve length and cut, dress cut, heels height etc.). The attributes are divided into two groups:

- fashion attributes – pertaining to particular characteristics of clothes in terms of shape or cut (e.g. sleeve length, dress style, heel type etc.);
- visual attributes – pertaining to the purely visual, non-fashion specific characteristics (colour, brightness, vividness, pattern).

Other concepts defined within the ontology cover different types of materials and possible usage contexts for a given outfit.

3.2 Clothing Dataset

The data under consideration is organized as follows. Each item of clothing is described using a set of attributes, appropriate for a given cloth type. However, none of the attributes is mandatory, hence different items can be described using different sets of attributes even if they belong to the same category and/or type.

An example of a semantic description of one item is given below:

- type – shirt;
- attributes – colour: sky blue; pattern: stripes; brightness: 0.8; vividness: 0.1; sleeve length: long; sleeve cut: slim; collar type: Italian; material: cotton.

Given the cloth type “shirt”, the category “upper body” can be inferred.

The ontology contains mostly categorical attributes (e.g. sleeve length) and several real-valued ones (e.g. brightness). The colour attribute receives special treatment, as will be explained in the next section.

The most important concept forming the dataset is cloth set (or outfit), consisting of several cloth items of any type. No constraints have been imposed on the contents of a set. Some typical sets contain the following combinations of elements (in terms of the general cloth category):



Fig. 2. Exemplary outfit from the obtained fashion dataset, containing two reference items – a red dress and a denim jacket (Color figure online).

- 1x upper body, 1x lower body, 1x outerwear, 1x footwear (e.g. shirt, trousers, jacket, shoes);
- 1x whole body, 1x footwear, 2x accessories (e.g. dress, high-heels, purse, scarf);
- 2x upper body, 1x lower body, 1x headwear (e.g. shirt, pullover, jeans, hat).

Given the extreme variability of outfit composition in real life, the flexibility achieved using the above approach is crucial to properly represent fashion information. However, this level of flexibility poses a problem when trying to compare outfits or to search for an outfit similar to a given one.

4 Clothes Similarity

For the purpose of comparing clothes two similarity measures need to be defined. First, we introduce means to compare two single cloth items. Then, based on this, the measure of similarity for cloth sets (outfits) is defined.

4.1 Cloth Item Similarity

When comparing cloth items, two fundamental pieces of information need to be taken into consideration: cloth type and cloth attributes.

Cloth Types Similarity. First, we need to deal with cloth type. Two pieces of clothing of distinctively different types (e.g. shirt and shoes) must be considered completely different, regardless of their specific fashion attributes. Two items of the same type (e.g. two shirts) should be considered similar, with the value of similarity depending on the values of detailed cloth attributes. However, there are certain items of clothing, which could be considered similar, even if the types don't match exactly (e.g. shirt and blouse, jeans and trousers). Hence, we introduce a similarity index μ_t for two cloth types t_1 and t_2 :

$$\mu_t(t_1, t_2) = \begin{cases} 1 & \text{if } t_1 = t_2, \\ 0.5 & \text{if } t_1 \text{ is ancestor of } t_2, \\ 0 & \text{otherwise.} \end{cases} \quad (1)$$

The relations within cloth types taxonomy are utilized in order to detect similar cloth types. More detailed ways of assigning similarity index based on the distance in hierarchy tree were tested. However, a simplified approach of assigning 0.5 value to types connected by ancestor/descendant relationship has been found to be sufficient and significantly faster and easier to implement.

Fashion Attributes Similarity. As for the cloth attributes, both categorical and real valued attributes must be uniformly taken care of. Bearing the above in mind, we introduce the following measure of similarity.

Let i denote an item of clothing, described by a set of attributes $p_1, p_2, \dots, p_n$. Given two values v_1 and v_2 of a particular attribute p_i , we introduce a similarity index $\mu_a(p_i, v_1, v_2)$, defined differently for different types of attributes:

$$\mu_a(p_i, v_1, v_2) = \begin{cases} \mu_{ac}(v_1, v_2) & \text{if } p_i \text{ is a categorical attribute,} \\ \mu_{an}(v_1, v_2) & \text{if } p_i \text{ is a numerical attribute,} \end{cases} \quad (2)$$

where μ_{ac} and μ_{an} denote similarity indices for categorical and numerical (real-valued, normalised) attributes respectively:

$$\mu_{ac}(v_1, v_2) = \begin{cases} 1 & \text{if } v_1 = v_2, \\ 0 & \text{if } v_1 \neq v_2, \end{cases} \quad (3)$$

$$\mu_{an}(v_1, v_2) = 1 - |v_1 - v_2|. \quad (4)$$

Colour Values and Colour Sets Similarity. A special treatment is given to the colour attribute, for two reasons. First, the colour is described by categorical values (red, blue, yellow and so on), but the similarity between two colours can be calculated if the names are mapped into RGB values. Second, colour attribute can take several values for the same item (e.g. a shirt is red and white). In order to compare colours of two cloth items, two concepts need to be introduced: similarity between two colours and similarity between two sets of colours.

Assuming that colour v_i is described in RGB space as (r_i, g_i, b_i) , the similarity index for two values of colour is defined as follows:

$$\mu_c(v_1, v_2) = 1 - \frac{\sqrt{w_r(r_1 - r_2)^2 + w_g(g_1 - g_2)^2 + w_b(b_1 - b_2)^2}}{255}, \quad (5)$$

where w_r , w_g and w_b denote weights applied to particular RGB components. Given the characteristics of human perception, the following values are suggested:

$$w_r = 0.2989, \quad w_g = 0.587, \quad w_b = 0.114. \quad (6)$$

Assuming that two items of clothing i_1 and i_2 are described using two colour sets c_1 and c_2 , the following procedure for determining similarity between c_1 and c_2 is performed:

1. for each colour pair $(v_i, v_j) \in c_1 \times c_2$ calculate $\mu_c(v_i, v_j)$;
2. for each colour $v_i \in c_1$ find the most similar colour $v_{1,i}^{sim} \in c_2$;
3. for each colour $v_j \in c_2$ find the most similar colour $v_{2,j}^{sim} \in c_1$;
4. calculate mean values μ_1 and μ_2 of similarity indexes found in two previous steps, according to the following formulas:

$$\mu_1 = \frac{1}{|c_1|} \sum_{i=1}^{|c_1|} v_{1,i}^{sim}, \quad \mu_2 = \frac{1}{|c_2|} \sum_{j=1}^{|c_2|} v_{2,j}^{sim}, \quad (7)$$

where $|c_i|$ denotes set cardinality;

5. take the smaller of μ_1 and μ_2 as the final similarity index.

Aggregated Cloth Items Similarity. The similarity measure between two cloth items is loosely based on Jaccard index, combined with the above similarity index for attributes, and defined as follows. For two items i_1 and i_2 being compared, let t_1 and t_2 denote cloth types, and P_1 and P_2 – the respective attribute sets. The total number of attributes and the number of common attributes is determined, then similarity indices are calculated for common attributes. The final measure of similarity between items is defined as:

$$s(i_1, i_2) = \frac{\mu_t(t_1, t_2) + \sum_{p \in P_1 \cap P_2} \mu_a(p, v_{p1}, v_{p2})}{1 + |P_1 \cup P_2|} \quad (8)$$

where v_{p1} and v_{p2} denote the value of p attribute for i_1 and i_2 respectively and $|\cdot|$ denotes set cardinality.

The above similarity measure takes into consideration both cloth type and specific fashion attributes of any type.

4.2 Cloth Set Similarity

Based on the cloth item similarity measure, the cloth set similarity measure has been developed. Let us first consider a composition of cloth set and possibility of comparing elements belonging to two sets. As mentioned before, no constraints exist as to what types of clothes can coexist within an outfit. Hence, two outfits being compared might consists of different number of items, belonging to different types, and even to different general clothing categories (see examples in Sect. 2). In the proposed approach we compare pairs of items from both sets belonging to the same general categories. For example, let's assume two sets consisting of:

- shirt, pants, shoes;
- sweater, jeans, hat.

In such a case the shirt would be compared to the sweater (category: upper body), the pants to the jeans (category: lower body), while shoes and hat have no match and are ignored in attributes comparison.

The final similarity measure consists of two components. The first one measures the similarity of composition in terms of types of clothing only. The second one measures the similarity of matching items in terms of detailed fashion attributes. Using weights the importance of both components may be controlled.

Let us introduce the following notation:

- o_1 and o_2 – two outfits (cloth sets) being compared;
- M – a set containing all matching (i_i, i_j) item pairs, where $i_i \in o_1$, $i_j \in o_2$, and both i_i and i_j belong to the same general category;
- C_{all} – a set containing all general categories present in any of o_1 and o_2 ;
- C_{common} – a set of common categories, present in both of o_1 and o_2 .



Fig. 3. Exemplary results of searching for single items with semantic attributes similar as the reference jacket i_{ref} . The values of similarity index $s(i_i, i_{ref})$ are given below each image.

Then the final similarity measure between outfits o_1 and o_2 can be defined as:

$$s(o_1, o_2) = w_1 \frac{|C_{common}|}{|C_{all}|} + w_2 \frac{\sum_{(i_i, i_j) \in M} s(i_i, i_j)}{|M|}, \quad (9)$$

where $s(i_i, i_j)$ denotes similarity between items, introduced in the previous section, and $|\cdot|$ denotes a cardinality of set. By default it is assumed that:

$$w_1 = w_2 = 0.5.$$

However, the validity of these values depends on the dataset under examination, especially on the variance in outfit composition in terms of cloth types/categories and on the completeness of semantic attributes data.

5 Experimental Results

The proposed method for comparing outfits has been tested using a dataset collected from various fashion-related web sites, especially fashion blogs. The images depicting people wearing the outfits were collected and then annotated using the developed fashion ontology. Annotations were prepared by analysts based on users' descriptions and visual examination.

The test dataset contains 800 outfits (500 women, 300 men) of varying composition and characteristics. First, the similarity measure for single items was tested. Some clothing items were selected randomly and for each of them the most similar items were searched for. Exemplary results of finding items similar to the reference one (to the jacket visible on Fig. 2) are shown in Fig. 3.



Fig. 4. Exemplary results of searching for outfits with similar semantic attributes. The first image in each row is a reference outfit, the following three outfits are found to be similar.

Next, the similarity measure for complete outfits was tested. For each outfit in the dataset the most similar outfits were searched for. Some representative results are shown in Fig. 4.

The obtained results show, that the results of applying the proposed similarity measure to searching for similar single items is fully satisfactory. As for seeking similar outfits, the results are satisfactory in terms of fashion attributes (length, cut, types of clothes etc.). However, the similarity in terms of colours and visual patterns, as perceived by users, is not very good. However, this should be expected, given that when calculating the similarity index, the fashion attributes have more impact on the outcome, than visual attributes (colour, brightness, pattern).

Further research is currently in progress aimed at incorporating certain computer vision methods in the similarity measure, in order to find outfits which are similar both in terms of semantic description and subjectively perceived visual characteristics.

6 Conclusions

The approach described in this paper can be used to calculate similarity between single items of clothing and between complete outfits, consisting of any number of items of different types and characteristics. The semantic description used in the research, based on a developed fashion ontology, allows for great flexibility in representing cloth characteristics, both in terms of possible continuous and seamless extension, and dealing with incomplete description.

The experiments performed on real data gathered from various fashion-related social networking websites, confirmed the validity of the proposed approach and indicated possible areas of further enhancement. The next step in planned research will be integration of computer vision methods and semantic description in order to provide similarity measure more sensitive to visual information, and hence to better facilitate searching for similar and/or matching cloth items and outfits.

Acknowledgements. The project “Construction of innovative recommendation based on users styles system prototype: FireStyle” (original title: “Zbudowanie prototypu innowacyjnego systemu rekomendacji zgodnych ze stylami użytkowników: FireStyle”) is co-founded by European Union (project number: UDA-POIG.01.04.00-30-196/12, value: 14.949.474,00 PLN, EU contribution: 7.879.581,50 PLN, realization period: 01.2013–10.2014). European funds – for the development of innovative economy (Fundusze Europejskie – dla rozwoju innowacyjnej gospodarki).

References

1. Chen, H., Gallagher, A., Girod, B.: Describing clothing by semantic attributes. In: Fitzgibbon, A., Lazebnik, S., Perona, P., Sato, Y., Schmid, C. (eds.) ECCV 2012, Part III. LNCS, vol. 7574, pp. 609–623. Springer, Heidelberg (2012)
2. Chen, Q., Li, J., Liu, Z., Lu, G., Bi, X., Wang, B.: Measuring clothing image similarity with bundled features. *Int. J. Cloth. Sci. Technol.* **25**(2), 119–130 (2013)
3. Di, W., Wah, C., Bhardwaj, A., Piramuthu, R., Sundaresan, N.: Style finder: Fine-grained clothing style detection and retrieval. In: 2013 IEEE Conference on Computer Vision and Pattern Recognition Workshops (CVPRW), pp. 8–13. IEEE (2013)
4. Finnie, G., Sun, Z.: Similarity and metrics in case-based reasoning. *Int. J. Intell. Syst.* **17**(3), 273–287 (2002)
5. Liao, T.W., Zhang, Z., Mount, C.R.: Similarity measures for retrieval in case-based reasoning systems. *Appl. Artif. Intell.* **12**(4), 267–288 (1998)
6. Liu, Z., Wang, J., Chen, Q., Lu, G.: Clothing similarity computation based on t-lac. *Int. J. Cloth. Sci. Technol.* **24**(4), 273–286 (2012)
7. Zhang, W., Begole, B., Chu, M., Liu, J., Yee, N.: Real-time clothes comparison based on multi-view vision. In: Second ACM/IEEE International Conference on Distributed Smart Cameras, ICDSC 2008, pp. 1–10. IEEE (2008)

Intelligent Information and Database Systems

8th Asian Conference, ACIIDS 2016, Da Nang, Vietnam,

March 14-16, 2016, Proceedings, Part I

Nguyen, N.T.; Trawiński, B.; Fujita, H.; Hong, T.-P. (Eds.)

2016, XL, 815 p. 251 illus. in color., Softcover

ISBN: 978-3-662-49380-9