Color Histogram Analysis of Virtual Garment Fit Image for Automated Fit Evaluation

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Keywords: garment fit analysis, virtual fitting, histogram algorithms, body types, image similarity, clothing development, color maps, bhattacharyya method

Clothing fit is a major factor influencing the customer's purchase decision, but it is difficult to directly evaluate the physical fit of the garment online. The technology of virtual clothing has been introduced to address the issue of clothing fit in e-commerce, and is in the commercialization stage (Kim et al., 2019). However, clothing fit research is complex due to the need for cooperation between experts and consumers, and it is difficult to study the fit of actual mass-produced clothing for a large number of consumers (Gill, 2015). Therefore, there is a need for a method to analyze multiple virtual garments without relying on experts. In this study, a number of clothing fit images were quantitatively analyzed using histogram analysis algorithms to achieve mass customization of garment fit. Clothing patterns were draped on human models of various body types, and garment fit images were represented by strain maps and distance maps. The front, side, and rear views of the wearer were then captured and used for analysis. The histogram analysis method of virtual garment fit images is expected to improve the customization clothing development and fit analysis process in the current expert-dependent system, as it allows for fast and objective quantification of similarity among multiple images.

Most apparel CAD software can show drape simulation pressure levels using various color shades, aiding users in assessing subjective fit (Brubacher et al., 2023). Typically, factors like stress, tension, and strain are visualized in colors, indicating applied force or fabric deformation degree. The distance or fitness item reveals the gap between the virtual fabric and the human body model. As there's no established standard for evaluating clothing simulation realism (Li et al., 2023), CAD companies might differ in how they display color maps. Yan & Kuzmichev (2020) utilized CLO 3D (version 5.0.156.38765, CLO Virtual Fashion, Korea) to evaluate shirt fit. Contrastingly, in fields like topographic and medical image analysis, color maps were quantitatively assessed using pixel-based image similarity analysis (Lv et al., 2019; Renukadevi et al., 2022). Although virtual clothing images can feature multiple color maps, objective analyses with these are still limited in use.

The comparison of image similarities was performed using OpenCV's cvCompareHist function, an open-source library for real-time image processing. This function calculates the similarity between two images by providing a numerical value when specifying the reference image, the comparison image, and the algorithm type. Six reference images were generated: screenshots of strain maps and clearance maps (equivalent to distance maps) from three directions (front, side, and back) of simulations of the template pattern on the average body model. For the comparison images, sixty screenshots representing 10 body types were used. These body models were chosen based on the KS K 0051 (Korean Standard Association, 2019) criteria, using 3D scan data from the Korean Human Body Dimension Survey (SizeKorea, 2022), with major body dimensions (height, bust circumference, waist circumference, hip circumference) falling within average ranges or significantly deviating from them, later adjusted for left-right symmetry. The pattern template was derived from CLO 3D's women's T-shirt pattern and adapted into a sleeveless top. The comparison algorithms included Correlation, Chi-square, Intersection, Bhattacharyya, and EMD

(Earth Mover's Distance) as introduced in the official documentation of OpenCV. As there is no known best algorithm for virtual garment color map data, all five were utilized.

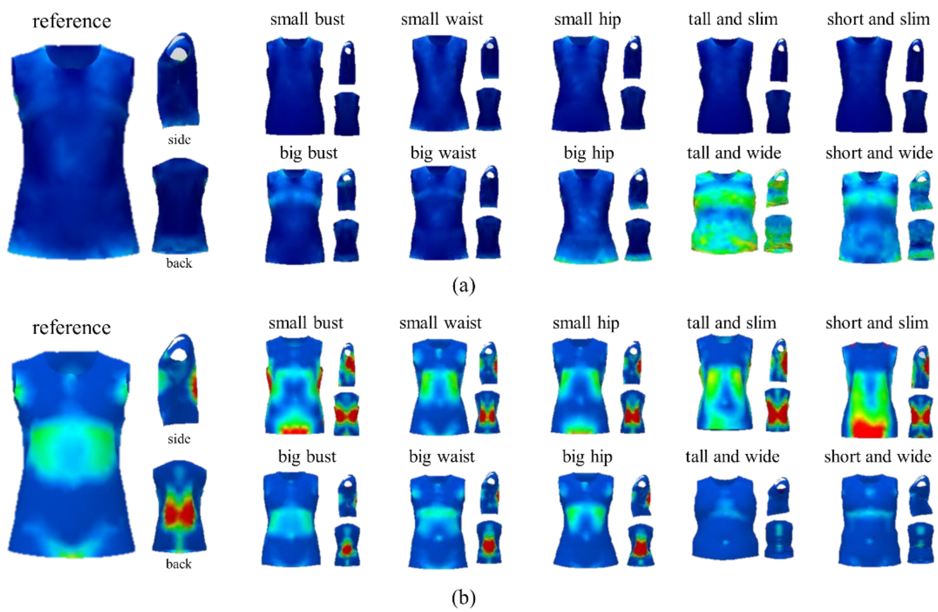

Figure 1. Example of a virtual garment fit image: (a) Strain map, (b) Clearance map.

The following figures show examples of front strain maps of similarity analysis results by algorithm (Figure 2) and similarity analysis results by color map (Figure 3). The more similar the two images are, the closer the score to 1 for correlation and intersection, and the closer the score to 0 for the rest of the algorithm.

Figure 2. Example of similarity analysis results by algorithm

Correlation and intersection analysis yielded similar results, as did chi-square and EMD analysis. Chi-square yielded notably high values for visually distinct images, while the clearance map's similarity wasn't well discerned in the correlation-based color map analysis. Bhattacharyya method demonstrating the most stable similarity across body types, color map types, and garment views among the five algorithms.

Figure 3. Bhattacharyya similarity scores for strain map and clearance map

In the strain map of Figure 3, the front panel score of short and slim (ss) was lower than that of short and wide (sw), while the clearance map shows the opposite, which implies that the fit image of ss closely resembles the reference image in the strain map, whereas sw demonstrates greater similarity in the clearance map.

Through histogram analysis of virtual garment fit images, it was possible to quantify the similarity of fit images. This method can be applied to select samples with high similarity to the reference image or identify samples with low similarity, allowing for selective fit modifications when there are multiple samples. Further research will be conducted to provide valuable tools for clothing development by comparing the similarity in specific regions of virtual garment images with subjective similarity perception results of humans.

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This work was supported by the National Research Foundation of Korea (NRF) Grant funded by the Korean Government (MSIP) (RS-2023-00208052) and Korea Institute for Advancement of Technology (KIAT) grant funded by the Korea Government (MOTIE) (P0012770, Professional Human Resources Training Project).