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The development of an intelligent system for customized clothing making

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ABSTRACT

This study presents the development of an intelligent system for customized clothing making. The system involves body dimension collection, clothing pattern generation and fabric cutting. First, body dimensions can be collected by analyzing the 3D scanning images or 2D photographs. Further, the clothing patterns can be generated by using computer-aided design (CAD) techniques based on the collected dimensions. By presenting the generated clothing patterns in DXF (Drawing Exchange Format), the CNC laser-cutting machine can then cut the fabric into pattern pieces automatically. Finally, by integrating the system with the processes of garment sewing, fitting test and final adjustment, the concept of customized clothing making can be realized. It can not only assure good fitness of the customized clothing but also reduce human efforts, costs, and production time.

1. Introduction

Nowadays, there is a growing demand from consumers to purchase customized products at lower prices with faster delivery. For manufacturers, reducing production time and saving personnel expenses contribute to the increase in competitiveness and the further growth in profits. In the apparel industry, in order to meet these needs on both ends, the concept of mass customization may be among the best solutions. The critical issues are using advanced instruments to collect body dimensions more rapidly, applying CAD/CAM (Computer-Aided Design/Manufacturing) technologies to generate clothing patterns and cut fabric automatically, and developing an integrated system to facilitate efficient production.

Traditionally, body dimensions were collected by using direct measurement instruments, such as calipers and measuring tapes. Nevertheless, the precision of the measurements could be affected by intra- and inter-observer errors, and the measurement procedure tended to be tedious and time-consuming. With the advancement of modern optical technologies, it is now possible to measure human body efficiently with non-contact methods. The 3D whole body scanner is a state-of-art optical measurement system. By scanning through the human body, 3D point clouds on the body surface can be captured, and further applications such as body dimension collection can be performed (Istook & Hwang, 2001; Paquette, 1996). For the purpose of effective dimension collection, some anatomical landmarks on the human body need to be specified in advance. Previously, color markers were utilized to locate the landmarks to help for easy identification (Wang, Wu, Lin, Yang, & Lu, 2007). This method is quite effective but requires much time for pre-marking and might incur human errors. In order to eliminate the requirement of human intervention, an automated landmarking method was proposed (Lu & Wang, 2008). It reduces the processing time greatly and provides satisfactory precision as well. However, the application of 3D scanning technology is somehow limited due to the high equipment cost and poor portability. Thus, an alternative approach is required for efficient body dimension collection.

With 2D photographs, it is also possible to collect some basic body dimensions, such as heights and lengths (Meunier & Yin, 2000). Besides, by applying some mathematical models, circumference data can be approximated. In order to obtain the quality image of human body, the color and background arrangement need to be well controlled. Calibration of the camera is also necessary before taking photographs. The cost of a digital camera is rather low, and it is much easier to use as comparing with the 3D body scanner. However, the number of collected body dimensions is relatively limited, and the approximated circumferences may be less accurate. Therefore, there is a trade-off between using 3D scanning data and 2D photographs for body dimension collection.

For clothing pattern generation, it is usually done by skilled pattern makers based on the collected body dimensions and the shape features they observe. This requires a great amount of expertise and experience and thus induces considerable labor costs. With the development of CAD/CAM technologies, the computer software can now facilitate the efficiency of clothing pattern generation (Kang & Kim, 2000; Stylios, Fan, Sotomi, & Deavon, 1992). Based on the mathematical expressions for necessary measures, the computerized construction of clothing patterns can be developed (Petrak & Rogale, 2001). Besides, with the computer-generated

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digital human models, patterns can be created and visualized in a virtual environment (Kang & Kim, 2000; Petrak & Rogale, 2006). Due to the consistency of computer programs, patterns can be generated using the same rules repeatedly. Moreover, the data can be stored and retrieved with ease. It has the flexibility of generating a different type of clothing pattern rapidly without taking the measurements again. As for fabric cutting, the CAD/CAM technology also enables automatic fabric cutting based on the patterns being generated by the CAD system.

As mentioned above, there are some existing technologies enabling the automation of customized clothing making. However, it lacks thorough development and efficient integration of the respective processes. Thus, in this study, an integrated system was proposed for customized clothing making, including body dimension collection, garment pattern generation and fabric cutting. The two methods of body dimension collection are illustrated in the following section. Then the procedure of clothing pattern generation and fabric cutting are described in the next section. Finally, the integration and application of the system are presented.

2. Body dimension collection

In this study, two methods were proposed for body dimension collection. One is based on 3D scanning data, and the other is based on 2D photographs. The users may select either of the two methods according to their needs.

2.1. Body dimension collection from 3D scanning data

A Vitronic Vitus-3D 1600 whole body scanning system was employed to construct 3D digital human models and to help to collect body dimensions. Prior to scanning, the scanner has to be calibrated, whereas the lighting condition is well-controlled. For assuring the quality of scanning images, the subject was asked to wear a set of scanning attire and cap, and to adopt a standard posture during scanning.

In order to measure body dimensions from 3D scanning data efficiently, an automated landmarking method has been developed by the authors (Lu & Wang, 2008). After noise reduction, the whole body scan can be first segmented into body parts. Then the initial searches are performed to locate the possible positions of the landmarks based on the statistics derived from a large anthropometric database. After that, four algorithms are adopted to identify different landmarks. Each algorithm can help to extract several landmarks with similar characteristics (Lu & Wang, 2008).

With the 12 landmarks and three characteristic lines extracted, we are able to collect 104 body dimensions. Linear dimensions such as heights, breadths, and depths can be measured by calculating the Euclidean distance between two landmarks. The circumferences and contour lengths can be calculated by using the convex-hull polygonal approximation method. The methods of landmarking and dimension collection have been evaluated with 189 human subjects and were found to be both effective and robust (Lu & Wang, 2008).

2.2. Body dimension collection from 2D photographs

The alternative method for collecting body dimensions is based on the image analysis of 2D photographs. A SONY™ DSC-P9 digital camera was used in this study. Prior to photographing, the camera has to be calibrated with the standard procedure. In order to reduce the distortion caused by the perspective effect, the calibration model has to be built in advance. A horizontal line and a vertical line with specified lengths were taped on a 2.0 m × 1.0 m rectangular frame. For obtaining the correct value of the horizontal distance ($DH_{correct}$), the measured value ($DH_{measured}$) should be multiplied by the ratio of the specified length of the horizontal line ($LH_{specified}$) to its measured value ($LH_{measured}$). Similarly, the vertical distance can be corrected by the same method.

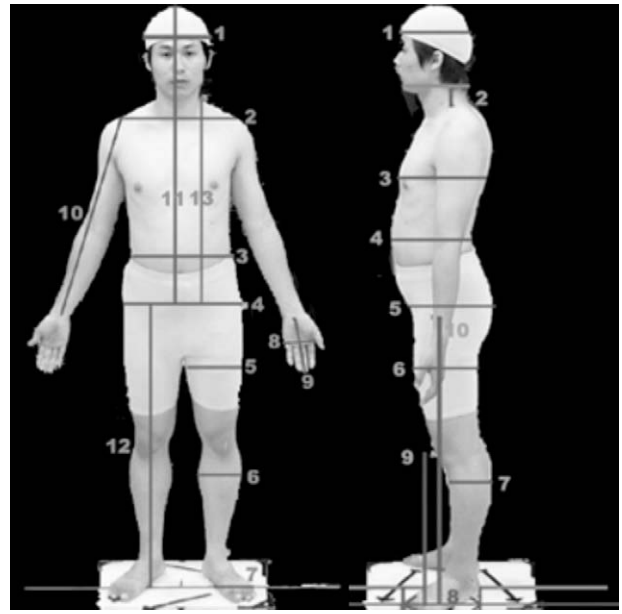

Fig. 1. The 23 linear dimensions collected from 2D photographs.

$$DH_{correct} = DH_{measured} \times \frac{LH_{specified}}{LH_{measured}} \tag{1}$$

$$DV_{correct} = DV_{measured} \times \frac{LV_{specified}}{LV_{measured}} \tag{2}$$

While taking photographs, the subject was asked to stand in front of a mono-color background with two photographs being taken from the front view and side view. After the two photographs are taken and verified, 36 landmarks are identified manually to define the starting and ending points for collecting body dimensions. Then a total of 23 linear dimensions can be collected automatically, as shown in Fig. 1. The 13 height and width measures can be obtained from the front-viewed image (left), whereas the side-viewed image enables data collection of the 10 depth measures (right).

In addition, the collected dimensions are used to generate a 3D model of the subject. There are six standard human models of different sizes for males and females available. After comparing the collected dimensions of the subject with the corresponding dimensions of the standard models, the most fitted one can be identified. Then the standard human model is deformed and adjusted based on the key dimensions of each body segment. Thus, a customized 3D human model is constructed for the subject, which helps to collect eight circumference measures. In other words, there are a total of 31 dimensions obtained for clothing making with the developed system.

To evaluate the dimensions collected from 2D photographs, comparisons were made with the measurements obtained by the contact method and by the 3D scanning method. For the 10 subjects tested with the system, the differences of the measurement results among the three methods were found to be acceptable by considering the criterion given by experienced tailors (Wu, 2003). In other words, the body dimensions collected from the proposed system have satisfactory accuracy for apparel uses.