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Fully vision-based automatic human body measurement system for apparel application

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ABSTRACT

A number of intelligent vision systems have been applied to the apparel industry. Among them, few existing systems have been utilized directly for the production of custom tailoring. Therefore, we propose a portable tailor assistant system that can measure the dimensions of the customer's body automatically. The proposed system, which uses a vision-based method and system package, provides comfort and privacy for customers and cost savings and convenience for tailors. It works in four steps: frontal color image processing based on background subtraction and marker recognition, frontal IR image processing for robust marker detection, foot IR image processing for manufacturing customized insoles, and final measurement based on characteristics of the human body. Through experiments, the system is proven to measure the dimensions of human body parts quickly and robustly in cluttered indoor environments. Therefore, the vision-based automatic human body measurement system will be a breakthrough in the clothing industry.

1. Introduction

The apparel industry has been rapidly automated and the production of almost all types of ready-made clothes has become possible. However, an individual personality has caused customers to prefer wearing tailor-made clothes in their daily lives. Customers have not been deterred by the high cost because custom-tailored clothes enable them to disguise imperfections in body shape. This trend has increased the demand for custom-tailored clothes, even for uniforms or work clothes, and requires novel clothing production services that provide customers with tailor-made clothes of good quality in a short time. However, the customized clothing service has two impediments: the difficulty of measuring the physical dimensions for many customers in a very short time and a high price due to particular production processes. In addition, from the customer's perspective, the current body measurement method in traditional anthropometry has three serious problems: disclosure of one's body size, repulsion toward opposite-gendered tailors, and accidental manipulation by word-of-mouth communication. Tailors can overcome these problems by measuring body size using a current scanning method and then automatically saving the customer's information. However, the scanning method is not portable, and the use of three-dimensional scanners requires a huge setup space and a high purchase cost. It also requires customers to be naked, which may deter some of them. In addition, saving the complete scanned data requires a huge capacity. To solve these problems, this paper proposes a portable body measurement system based on the RGB–IR vision method. The proposed system can be easily set up in a small space and carried out by a single tailor. Also, it measures a customer's body size robustly and quickly at a small cost with no physical contact. The customer no longer needs to be naked and just

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has to wear a vest with RGB–IR markers. The system works in four steps: frontal color image processing that consists of background subtraction and marker recognition, frontal IR image processing for robust marker detection, foot IR image processing, and final measurement using predefined characteristics of the human body.

The remainder of this paper is organized as follows. In Section 2, existing body measurement systems are reviewed. Then, the proposed system is described in detail in Section 3. In Section 4, experimental results using the system are given and discussed. Finally, the conclusion and suggestions for future research are given in Section 5.

2. Related work

Existing body measurement systems are primarily scanning-based and have gradually evolved. In past studies, scanning systems have been mainly classified into two categories: laser scanning and vision-based scanning [1].

First, the body measurement systems using a 3D laser scanner focus on calculating body circumference sizes from the complete 3D data [2]. Although this type of system can compute circumference sizes with a high degree of accuracy, it produces unacceptable results for vertical sizes (e.g., the length of an arm). An optimization method using a non-linear equation has been proposed to address this problem [3]. However, there are a couple of problems with this method: the size measurement determined using statistical parameters does not satisfy requirements for individual accuracy and the parameters must be adjusted for each customer. Therefore, these methods are difficult to use for bulk orders and production, although they have been attempted [4]. Also, the scanning-based systems can be time-consuming (scanning takes at least 20 s) and it is often technically difficult to recalculate useful body size measurements from 3D scanning data [5]. For apparel mass customization, a measurement method has been proposed that is based on user body scanning and clothes modeling [6]. However, this method cannot measure vertical sizes accurately because it uses horizontal laser lines from two laser projectors and cameras. There have also been research studies on adapting the particular shape of a customer's body [7,8]. However, these studies were conducted on limited subjects (e.g., Chinese adult or old woman's pants). In addition, a portable 3D body scanner system has been proposed, but it requires customers to be naked [9]. Nevertheless, many body fit studies using scanning-based systems have been attempted in a variety of ways [10].

Second, body measurement systems using camera image processing are currently getting a lot of attention in the clothing industry. First, a system that uses body landmarks (e.g., bust points and navel) is fairly fast and accurate [11]. However, this system also requires customers to be naked and the landmark positions of an individual human body to be known. If the requirements are not satisfied, these systems require user intervention and become more time-consuming [12]. Recently, the emergence of the RGB-D (RGB-Depth) sensor has attracted considerable research interest [13]. However, this scanning method requires customers to wear tights, which is a problem. Although a more practical approach using a skeleton algorithm and depth image was proposed [14], it was not suitable for body circumference measurements. Also, a stereo vision-based approach was sensitive to light environments and the color of the user's clothes and did not make it easy to measure customers in a short time [15]. In this paper, we propose a portable body measurement system that overcomes the previous problems: requiring customers to be naked in order to locate the body's landmark positions, requiring customers to wear tights, the accidental manipulation of information by word-of-mouth communication, time-consuming computations, being unable to measure circumference sizes, system sensitivity to environmental lighting and the color of clothes, and so on. In addition, the proposed system can measure customers in a short time. Thus, the system could be a breakthrough in the clothing industry by improving the traditional anthropometric method and facilitating the tailor-made clothing production process.

3. Body measurement system

For manufacturing customized clothes, quick measurement of the body size of each customer is necessary. Such a measurement system should satisfy the following conditions:

(1) It should be able to measure customers in a very short time.
(2) It should be able to measure customers in a noncontact manner without requiring them to be naked.
(3) It should be able to measure customers accurately regardless of lighting conditions and the color of clothes.
(4) It should be able to measure body circumferences without body landmark information.
(5) The measured data should be able to be used directly in production systems.
(6) It should be portable, easy-to-build, and occupy a small amount of space.

To satisfy the above conditions, we employ the RGB–IR vision method and packaged devices for a tailor. As shown in Fig. 1, the packaged system was designed to enable easy installation in the indoor environment. The proposed system, which is based on a robust RGB–IR vision method, can quickly measure body size without requiring customers to be naked and without landmark information. In addition, a measuring vest with RGB–IR markers that can overcome robust lighting conditions and the color of clothes is used for customer privacy and convenience in a noncontact manner. The foot size for manufacturing custom insoles is measured by a toehold with an IR camera. Finally, the measured data that is minimized for directly manufacturing clothes can be displayed in an interface and transmitted to the production system using a website with the database. Next, we explain the RGB–IR image-based vision method and portable body measurement system package.