Development of an Intelligent Personalized Clothing Design System Based on Machine Learning Methods and Digital Anthropometry

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Abstract

This paper investigates the development of an intelligent personalized clothing design system based on machine learning methods and digital anthropometry. The study examines the integration of artificial intelligence, three-dimensional body scanning, computer vision, and computer-aided design technologies to improve the accuracy and efficiency of garment design. The proposed intelligent system enables automated anthropometric data processing, personalized pattern generation, virtual fitting, and continuous model improvement through self-learning algorithms. The research demonstrates that combining digital anthropometry with machine learning contributes to higher garment fit accuracy, reduced production costs, enhanced customer satisfaction, and more sustainable apparel manufacturing. The findings indicate that intelligent personalized clothing design systems represent a promising direction for the digital transformation of the textile and apparel industry within the framework of Industry 4.0.

Keywords

intelligent clothing design, machine learning, digital anthropometry, artificial intelligence, computer vision, personalized apparel, virtual fitting, 3D body scanning, CAD systems, Industry 4.0, smart manufacturing, apparel engineering.

The rapid development of artificial intelligence technologies has significantly transformed the global apparel industry, creating favorable conditions for implementing intelligent systems in garment design and manufacturing. Traditional clothing design methods are primarily based on standardized anthropometric measurements, which often

fail to accommodate the diversity of individual body characteristics. Consequently, this approach frequently results in poor garment fit, reduced customer satisfaction, increased production costs, and a high percentage of product returns.[1] Therefore, the development of intelligent personalized clothing design systems based on machine learning and digital anthropometry has become one of the most promising research directions in modern apparel engineering.

Personalized clothing design represents a new paradigm in which digital technologies, artificial intelligence, computer vision, and automated garment engineering are integrated into a unified intelligent decision-making system. Unlike conventional approaches, personalized design focuses on the unique morphological characteristics of each individual rather than relying solely on standard size charts. This transition from mass production to mass customization enables manufacturers to produce garments that provide superior comfort, functionality, and aesthetic quality while simultaneously improving manufacturing efficiency.[2]

Digital anthropometry has become one of the fundamental technological components of personalized apparel engineering. Modern three-dimensional body scanning systems allow the acquisition of hundreds of anthropometric parameters within a few seconds, providing highly accurate digital representations of the human body. Compared with traditional manual measurements, digital anthropometric technologies minimize measurement errors, improve data consistency, and create comprehensive digital body models suitable for computational analysis.[3]

The collected anthropometric information forms the primary database for intelligent decision-support systems. Advanced data processing techniques enable automatic identification of body proportions, posture characteristics, and morphological variations that directly influence garment construction. Consequently, designers are able to generate customized patterns that precisely correspond to the customer's anatomical

characteristics.

Machine learning technologies considerably enhance the analytical capabilities of digital anthropometry. Contemporary machine learning algorithms—including Artificial Neural Networks (ANN), Random Forest (RF), Support Vector Machines (SVM), Gradient Boosting Machines (GBM), and Deep Learning architectures—are capable of analyzing extensive anthropometric datasets and identifying complex nonlinear relationships between body measurements and garment fit.[4] Unlike conventional statistical models, machine learning algorithms continuously improve their predictive performance by learning from newly accumulated data, thereby increasing the accuracy of personalized design recommendations over time.

Another significant advantage of intelligent systems lies in their predictive capability. By analyzing historical anthropometric databases together with customer feedback regarding garment comfort and fitting quality, machine learning models can predict optimal design parameters before physical garment production begins. Such predictive analytics substantially reduce prototype development time, minimize production waste, and improve overall manufacturing efficiency.

Recent advances in computer vision have further expanded the practical application of intelligent apparel systems. Instead of relying exclusively on expensive industrial 3D body scanners, computer vision algorithms can reconstruct three-dimensional body models from multiple photographs captured by conventional smartphones or digital cameras. This technological innovation has significantly reduced the cost of personalized body measurement while making customized clothing services accessible to a much broader consumer population.[5]

The integration of computer vision, digital anthropometry, and machine learning establishes a comprehensive intelligent ecosystem capable of supporting every stage of personalized clothing development—from digital body measurement and

anthropometric classification to automated pattern generation and virtual garment fitting. Such systems represent an important step toward the realization of Industry 4.0 principles within the textile and apparel sector, where digitalization, automation, and artificial intelligence collectively enhance production quality and customer-oriented services.

An intelligent personalized clothing design system generally consists of several interconnected functional modules. The first stage involves collecting anthropometric information through three-dimensional body scanning or computer vision technologies. The acquired data are subsequently preprocessed to eliminate measurement noise, normalize anthropometric parameters, and construct an accurate digital body model. During the second stage, machine learning algorithms classify body types and predict optimal garment dimensions based on both current anthropometric measurements and previously accumulated datasets. Finally, computer-aided design (CAD) software automatically generates customized garment patterns and performs virtual fitting simulations before physical production begins.[6]

One of the most important characteristics of intelligent design systems is their ability to operate as self-learning platforms. After each completed order, customer evaluations regarding garment fit, comfort, and overall satisfaction are incorporated into the training dataset. This continuous feedback mechanism enables machine learning algorithms to refine predictive models, improve fitting accuracy, and adapt to newly emerging anthropometric patterns. Consequently, the performance of the intelligent system continuously improves without requiring extensive manual reprogramming.[7]

Virtual fitting technologies constitute another essential component of personalized clothing engineering. Three-dimensional simulation software allows designers and customers to evaluate garment appearance, comfort, and movement behavior before manufacturing. This significantly reduces production costs associated with repeated

sample development while simultaneously minimizing textile waste. From an environmental perspective, intelligent virtual prototyping also contributes to sustainable manufacturing by optimizing material utilization and decreasing unnecessary resource consumption.

Despite these technological advantages, several scientific and practical challenges remain. The protection of personal anthropometric data represents one of the most critical issues, requiring secure storage mechanisms and compliance with international data protection standards. Furthermore, differences among anthropometric databases, scanning technologies, and software platforms complicate the development of universally applicable intelligent systems. Additional research is therefore required to improve interoperability, algorithm robustness, and standardization of digital human models across different populations.[8]

From a scientific perspective, future research should concentrate on integrating artificial intelligence with cloud computing, digital twins, Internet of Things (IoT) technologies, and advanced manufacturing systems. Such integration would enable real-time anthropometric monitoring, automatic pattern adaptation, and highly responsive manufacturing environments capable of producing customized garments with minimal human intervention. These developments are fully consistent with the principles of Industry 4.0 and smart manufacturing, where intelligent decision-support systems play a central role in optimizing production processes.[9]

In conclusion, the integration of machine learning methods with digital anthropometry represents a transformative approach to personalized clothing design. Intelligent systems provide highly accurate body measurement, automated pattern generation, predictive fitting analysis, and continuous model improvement through self-learning mechanisms. Their implementation contributes not only to higher product quality and customer satisfaction but also to greater manufacturing efficiency, reduced

production costs, and improved sustainability within the apparel industry. Consequently, intelligent personalized clothing design systems are expected to become a key technological foundation for the next generation of digital fashion engineering and smart textile manufacturing.

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