Computer-Aided Design 45 (2013) 1426–1441

Contents lists available at ScienceDirect

Computer-Aided Design

journal homepage: www.elsevier.com/locate/cad

A study of surface reconstruction for 3D mannequins based on feature curves☆

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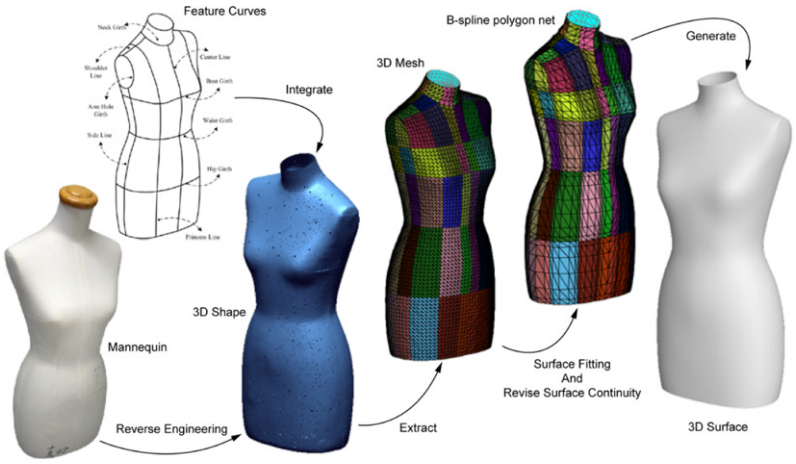
HIGHLIGHTS

- A feature curve based method for 3D mannequin surface reconstruction is proposed.
- The 3D mannequin is shaped by *B*-spline surfaces.
- A minimum energy method is used to improve the constructed mannequins' quality.
- 3D mannequin forms for different human factors can be morphologically generated.
- The feasibility of computer-aided fashion design and manufacturing is improved.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 13 September 2012
Accepted 25 June 2013

Keywords:
Fashion design
Reverse engineering
Surface reconstruction
Surface continuity
3D mannequin

ABSTRACT

Fashion Design is an industry closely connected to our daily life. Computer-aided fashion design can enhance the efficiency of product development, in which a 3D mannequin links the development and application of the entire design system, thus rendering the 3D mannequin data required for fashion design very important. This study proposed a systematic method for surface reconstruction of 3D mannequins based on feature curves. First of all, the study applied reverse engineering methods to scan a mannequin model commonly used in the fashion design profession by extracting grid points that represent the shape features from the scanned data after the segmentation of the mannequin model through feature surfaces. Then, the shape of the entire 3D mannequin is reconstructed using *B*-spline surfaces. Simultaneously, the continuity among the connected *B*-spline surfaces is adjusted with tangent vector adjustment methods based on the minimum energy required for improving the quality of the shaped surfaces. Finally, the 3D mannequin is applied to the computer-aided fashion design system being developed to achieve product development using synchronous design methods.

☆ This paper has been recommended for acceptance by Charlie C.L. Wang.

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http://dx.doi.org/10.1016/j.cad.2013.06.012

1. Introduction

Fashion design is an industry closely connected to our lives. When a designer proposes a variety of design ideas, determining how to specifically present these ideas is an important consideration. Currently there are two methods used in the development of apparel products: one is plane cutting, and the other is three-dimensional cutting. In methods based on plane cutting, the basic pieces required for fashion design are generated by mannequin forms, and patterning is performed through adjusting the scale of the shaped cutting pieces. By contrast, in three-dimensional cutting, designers directly come up with the garment designs on the mannequin to obtain the shaped cuttings of the 2D pieces required for production. Therefore, no matter which method is adopted for fashion design and development, all of the mannequins used by the design profession are important media for the concretization of design ideas; more specifically, the process is not only closely related to garment wearing fitness, but also affects the final appearance. On the other hand, human factors of the target consumer are also an important basis for the selection of mannequins. These data are determined by the sizes and relative positions of each feature line of the human body on the mannequin. In addition, for the same human factor measurement, the same mannequin form is not definitive, which further adds the complexity of the mannequin design. Generally speaking, fashion brands define the standard mannequin model based on consumer-related data, and then develop various mannequins of different sizes, thus creating the unique characteristics of each individual brand through garment cut, in addition to style design. Therefore, the selection of a suitable mannequin is an important step in the process of apparel product development. Once a mannequin is selected, details of the overall design can then be quickly and specifically presented.

When applying the 3D mannequin to the computer-aided fashion design, the mannequin should be designed based on different functions for different component levels. In the process of fashion design and manufacture, the mannequin not only completely represents the features and measurements for each portion of human body, but also corresponds to the need of customers with different figures. For this reason, each feature curve of the model has typical and specific significance, which allows the design of garments to be manufactured [1]. On the other hand, when a mannequin is applied to a garment display, the role of the mannequin is to accurately realize the display of 3D garments in the real world. Therefore, there is a demand for mannequins that can describe human features and figures; moreover, the mannequin should be able to display fashion design in different postures to showcase the characteristics of the garments. The target of this study was to develop a module for the generation of a 3D mannequin which can be applied to fashion design and manufacture and then realize the concept of 3D mannequin-aided fashion design. Hence, there are two main technical problems being addressed in this study: (a) how to generate a 3D mannequin of different sizes; and, (b) how to directly generate the control mesh for fashion design on the 3D mannequin. In these issues, how to generate different apparel surfaces by shape morphing, based on the relative control mesh defined and transformed by the position of the feature curves, is considered in this study. Other than the situation mentioned above, how to generate the design components of sleeves and pant legs from a 3D mannequin without mesh cutting and sewing is the other focus of this study. Through these issues, a method for surface reconstruction of a 3D mannequin based on feature curves is proposed in this study, where the reverse engineering methods are applied to scan the concrete mannequin. Through this technique, the surface partitions, which are segmented on the surface of the mannequin and defined by feature curves, can be constructed. More specifically, the surface partitions can obtain the grid points that represent the form features from the extraction of scanned points. Next, *B*-spline surfaces are selected to reconstruct the form of the entire 3D mannequin, and to ensure that the computation of surface fitting is more stable, the Gauss–Newton algorithm is applied. Meanwhile, revising the continuity of the interface among the *B*-spline surfaces with the tangent vector adjustment method based on the minimum energy is adopted to integrate surfaces with different features into a unity. When the form of the 3D model is transformed by adjusting the input of human factors, the whole 3D model can be composed of different blocks due to the surface partition. Without making changes for the features, the method mentioned above can generate different 3D mannequins of different sizes by scaling. Therefore, other design components can be generated on the original 3D model by a means analogous to assembling a brick wall, the application of which can be tailored for the construction of sleeves or pant legs. Finally, the 3D mannequin based on the proposed methodology is applied to a developing platform for computer-aided fashion design to verify the practicality of the study.

The remainder of this paper is organized as follows. Section 2 presents the literature review and highlights the current limits and necessary improvements. Section 3 details the methodology of this study, while Section 4 implements a case study of surface reconstruction for a 3D mannequin. Section 5 offers the results and discussion, with Section 6 providing conclusions potential trends for future research.

2. Literature review

Today, advances in information technology have made computer-aided fashion design a popular research topic. There is ample space for creativity in all of the design, manufacture, display and performance links of the industry. However, during the process, determining how to obtain the required mannequin is a problem that cannot be ignored. Using reverse engineering methods to scan the mannequin required for fashion design is the most common solution [2–4]. The whole mannequin model can be reconstructed based on semantic features and parametric surfaces, and then the shape surface can be unfolded to obtain the 2D pieces required by plane cutting techniques, which is an important function of 3D mannequins [5,6]. However, if the appearance of a human body can be directly scanned [7,8], not only would the measurement results of individual sizes be obtained, but the parametric design based on the statistical data could also be carried out to obtain the respective 3D mannequin for any size [9]. Although attaining the proper grouping of, and reconstruction from, the scanned data according to features are major challenges in the process, drawing on the 3D mannequin to generate 3D virtual clothing [10,11] can unleash the advantages of computer-aided design to achieve product development using synchronous design methods. This is also the goal that has been jointly sought by many related studies, especially studies on how to enable computer-aided fashion design to better fit design practices [12].

In the process of surface reconstruction from scanned data, using parametric surfaces to represent the entire 3D mannequin is a highly efficient procedure, which can also provide a variety of geometric information to help solve problems. Before surface reconstruction can begin, determining how to divide the scanned data into appropriate blocks using shape features [13,14] and re-simplifying the entire scanned data using slicing methods [15,16] are the most important preparations. When parametric surfaces are needed for the shape reconstruction of already partitioned blocks, the use of interpolation to obtain the minimum energy is a relatively common method [17–21], which is also widely used