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Control and optimization of human perception on virtual garment products by learning from experimental data

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ABSTRACT

This paper proposes an original study for controlling, in an Internet and virtual reality-based collaborative design platform, human perception on 3D virtual garments by adjusting fabric parameters, constituting the inputs to the garment CAD software. This study will permit the designer to determine the most relevant product through a number of interactions with the consumer. For this purpose, two sensory experiments have been realized on a small number of fabric samples. In the first experiment, we propose an active learning-based experimental design in order to find the most appropriate values of the fabric technical parameters permitting to minimize the overall perceptual difference between real and virtual fabrics in static and dynamic scenarios. The second sensory experiment aims to extract normalized tactile and visual sensory descriptors characterizing human perception on the concerned fabric samples. In the collaborative design process, these normalized descriptors will be used for communications between the designer and the consumer on perceptual quality of virtual products. By learning from the experimental data on identified inputs (fabric parameters of the CAD software) and outputs (sensory descriptors), we model the relationship between fabric technical parameters and human perception on finished virtual products. The method of fuzzy ID3 decision tree has successfully been applied in this modeling procedure. This model, combined with the corresponding garment CAD software and the learning data acquired from the two sensory experiments, constitutes the main components of the learning data-driven collaborative design platform. Using this platform, we have realized a number of garments meeting consumer's personalized perceptual requirements.

1. Introduction

Under the worldwide economic pressure, there is a strong need for industrial enterprises to quickly design new various products with short life cycles and low costs meeting personalized requirements of consumers in terms of functionalities, comfort and fashion style [1]. Based on generation of physical prototypes, the classical product design process is rather long, leading to high costs in human resource and production. In this context, the concept of collaborative design or co-design has been widely introduced in many industrial sectors such as automobile, furnishing, architecture, manufacturing and civil engineering for quickly delivering user-centered new products to the market.

Collaborative design represents the experience or process of a collaborative construction of new content in a virtual environment represented as avatars by multiple users through their communication and shared exploration of 3D visualizations [2]. The basic element of collaborative design is the Internet-based visual platform showing interactions between the product, the designer and the customer. Based on 3D visual models, new design methodologies, such as scenario-oriented design or context-oriented design [3], customized product design [4], are developed for dealing with different application contexts. They permit to realize the product design by visualizing a virtual person using the virtual product in a virtual scenario.

Collaborative design is very significant in garment industry because, compared with other domestic products, garments and their accessories are more human-centered in terms of body fitting, comfort and aesthetics. 3D virtual garment design using specific CAD software can be considered as an optimal combination of designers, computer technology and animation technology,

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permitting to realize and validate design ideas and principles within a very short time [5,6]. New knowledge and design elements on garments can be obtained from human–machine interactions. The application of virtual technology can effectively accelerate new product development, reduce design and production cost, and increase product quality in order to enhance the competitiveness of garment companies in the worldwide market [7,8].

The most appreciated CAD systems generating 3D virtual garments are based on mechanical models [9]. These models, built according to the mechanical properties of real cloth measured on devices such as KES and FAST [10], can effectively simulate fabric deformable structures and be accurate enough to deal with nonlinearities and deformations occurring in cloth, such as folds and wrinkles. Moreover, they can strongly interact with wearers or human body models. In practice, the perception of virtual garments can be modified by adjusting the technical parameters of the corresponding garment CAD software so that their visual and tactile effects are as close as possible to those of real garments. In this way, consumers and designers can control or enhance some sensory criteria such as softness, smoothness, rigidity and draping effects in virtual products according to their requirements. This approach is particularly interesting for designing new personalized products.

This paper presents a study for quantitatively characterizing human perception on virtual garment products and modeling its relation with the technical parameters of real fabrics. For this purpose, two sensory experiments are carried out on a small number of fabric samples for acquiring relevant learning data on the input (fabric technical parameters) and output (human perception on virtual garments) of the model.

In the first sensory experiment, the aim is to quickly identify the real values of the technical parameters for each specific fabric sample without performing any expensive and time-consuming physical measures. Taken as input data to the garment CAD software, these values will permit to minimize the overall perceptual difference between real and virtual products in static and dynamic scenarios. In this context, finding an optimal design of experiments permitting to estimate these values with minimal number of tests will become the key issue in this approach. However, the existing designs of experiments like orthogonal design [11] are mostly offline methods and the selection of new experimental data is independent of the previous evaluation results. In this context, online active learning seems to be an appropriate technique for solving this problem. In an online active learning algorithm, the learner encounters the data points sequentially, and at each instant, the model has to decide whether to query the current point and update the hypothesis. Viewed as an online active learning method, stochastic learning automata have been used for solving complex function optimization problems by successively computing the optimal action corresponding to the biggest value of the estimates of reward probabilities [12,13].

Compared with the existing online active learning methods optimizing complex functions, the context of our study is different in the following aspects: (1) Our objective is to minimize the human perception-based dissimilarity degree of virtual products related to a real product and then the required accuracy is relatively lower. (2) The number of concerned factors (parameters of the software generating virtual products) is very important. (3) The number of allowed learning data is even more limited and then the application of a stochastic optimization method is less practical.

In this paper, we proposed a new online active learning method for quickly and successively controlling human perception on virtual products towards the real product. First, it utilizes the uniform design [14] for acquiring the initial virtual fabrics. Next, according to the evaluated dissimilarity degrees of previous virtual samples related to the real product, we sequentially generate new samples. At each step of this procedure, the new samples are generated by enhancing searches on the most relevant garment design parameter, identified by the fuzzy logic-based data sensitivity criterion [15] of the design parameters. This procedure will permit us to identify through a very limited sensory tests the optimal values of the garment design parameters, which constitute the inputs to the garment CAD software and generate a virtual garment very close to the real one in both static and dynamic visual representations.

In the second sensory experiment, we extract a number of normalized tactile and visual sensory descriptors characterizing human perception on garment products and obtain the evaluation scores of the involved fabric samples on these descriptors. The classical descriptive sensory evaluation technique has been used in this approach. In practice, the perceptual quality of textile materials and garments is mainly related to tactile and visual properties. Visual properties essentially include fabric appearance, color, fashion style and garment fitting effects while tactile properties (hand feeling) are generally related to the nature of materials [10].

By learning from the input and output data acquired in the previous two sensory experiments, we model their relations using three techniques: linear regression, neural networks and fuzzy decision trees. In the context in which the number of learning data is relatively few, the experiments on different garment products have shown that the fuzzy ID3 decision trees are the most efficient tools in this modeling procedure.

The following sections are organized as follows. Section 2 presents the formalization of the concerned concepts and data, and gives a general structure of the proposed collaborative design platform. Sections 3 and 4 describe the details of the two sensory experiments for acquisition of the input and output learning data. In Section 5, we compare different modeling techniques for charactering the relations between the fabric technical parameters and human perception on the corresponding virtual garments. In Section 6, we give an example of garment collaborative design, showing how consumer's perceptual requirements can be taken into account in new design schemes. Finally, a conclusion is given in Section 7.

2. Formalization and general scheme

2.1. Formalization of the concepts and data

The concepts and data involved in this study are formalized as follows.

Let $S = \{S_1, S_2, \ldots, S_n\}$ be a set of n representative fabric sample.
Let $P = \{P_1, P_2, \ldots, P_m\}$ be a set of m fabric technical parameters served as inputs to the garment CAD software.
Let $SD_i = \langle SS_i, DS_i \rangle$ be the pair of dissimilarity degrees for the sample S_i. SS_i and DS_i represent the static (with photos) and dynamic (with video) dissimilarity degrees respectively, given by a group of evaluators by comparing the real and virtual fabric samples.
Let $D = \{D_1, D_2, \ldots, D_s\}$ be a set of s normalized sensory descriptors generated by another group of trained evaluators, for describing human perception on the virtual and real samples in S.
Let $In_i = (In_i^1, In_i^2, \ldots, In_i^m)^T$ be the normalized input vector, where In_i^j represents the value of the fabric technical parameter P_j for the fabric sample S_i, obtained from the Sensory Experiment I.
Let $Out_i = (Out_i^1, Out_i^2, \ldots, Out_i^s)^T$ be the normalized output vector obtained from Sensory Experiment II, where Out_i^j represents the value of D_j for the fabric sample S_i.