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Technical Section

Real-time virtual fitting with body measurement and motion smoothing ☆

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ABSTRACT

We present a novel virtual fitting room framework using a depth sensor, which provides a realistic fitting experience with customized motion filters, size adjustments and physical simulation. The proposed scaling method adjusts the avatar and determines a standardized apparel size according to the user's measurements, prepares the collision mesh and the physics simulation, with a total of 1 s preprocessing time. The real-time motion filters prevent unnatural artifacts due to the noise from depth sensor or self-occluded body parts. We apply bone splitting to realistically render the body parts near the joints. All components are integrated efficiently to keep the frame rate higher than previous works while not sacrificing realism.

1. Introduction

One of the most time-consuming stages of apparel shopping is trying the apparel on, which is not even possible in online stores. With advances in augmented reality technologies, virtual fitting rooms are slowly taking their place in both real and virtual stores [1,2] to improve the quality of apparel trial experience while making it faster. Advanced virtual fitting rooms show the apparel items either on the video of the user or on a virtual avatar, both scaled to reflect the user's body characteristics [3]. Some studies employ automatic body and garment segmentation [4] and physics-based garment and sewing simulation techniques [5,6] for a better fitting experience.

We present a novel virtual fitting room framework that provides all the basic features expected from such an application, along with enhancements in various aspects for higher realism. These enhancements include motion filtering, customized user scaling, and the use of a physics engine. The motion filtering process starts with temporal averaging of joint positions in order to overcome the high noise of the depth sensor. However, temporal averaging does not prove to be sufficient because unnatural movements take place due to limited recognition capabilities and self-occlusion. We implement customized joint angle filters, along with bone splitting, to let limbs twist in a more natural way. We also employ filtering on hip and knee joints to overcome the footskating problem.

The cloth pieces to be fitted on the user's avatar must first be scaled accordingly. To this end, we implemented body measurement process, which starts with depth map smoothing, in order to reduce noise. Afterwards, we utilize the filtered depth map along with filtered user joints to measure a set of parameters, which are used in conjunction to estimate the body height and shoulder width. These parameters are averaged over time to minimize the error.

The physics engine utilizes collision spheres and capsules to perform collision detection. We determine the correct sphere radii and positions during body measurements. The virtual avatar is aligned with a set of invisible spheres and capsules that are aligned with joints and limbs, which are updated in real time and used in collision detection. Cloth particles are also affected by gravity and inertia.

The rest of the paper is organized as follows. First, we give related work on virtual fitting rooms and depth sensors. Next, we provide an overview of the proposed approach, as well as the details of the cloth simulation engine, depth map filtering, body measurements, temporal averaging, and techniques used to cope with the inferior motion data problems. Then, we provide experimental results. Finally, we give conclusions and further research directions.

2. Previous work

Virtual fitting rooms have been a research subject for more than a decade. Protopsaltou et al. [7] developed an Internet-based approach for virtual fitting rooms, although it was not real time

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and required marker-based motion capture systems for animation. Zhang et al. [8] used a multi-camera system utilizing shell fitting space (SFS) [9] techniques to build a real time intelligent fitting room.

Advances in time-of-flight technology made depth sensors available at consumer-level prices with better performance. This prompted a wave of research based on depth sensors in various fields, such as rehabilitation [10], indoor modeling [11], and medicine [12]. Another topic that attracted significant attention from both researchers and companies is real-time virtual fitting rooms [13]. Giovanni et al. [14] developed a virtual try-on system utilizing a calibrated set of Kinect and high definition cameras, while comparing the two state-of-the-art depth sensing software development kits (SDKs)-OpenNI [15] and Kinect for Windows SDK [16]. While most frameworks utilize garment meshes with physics simulation [1,2], another intriguing approach is using a pre-recorded apparel image database from which the images are superpositioned onto the RGB video of the user [17,18].

One problem with depth sensors is the feeble quality and noisiness of the depth stream. This problem is analyzed in depth by Khoshelham and Elberink [19], who concluded that the standard deviation reaches 2 cm in a measuring distance of 3 m. Matyunin et al. [20] attempted to improve the quality by filtering with additional information from the attached RGB camera. To increase the quality of the models produced using depth data from a Kinect camera, Tong et al. [21] describe a scanning system for capturing 3D full human body models utilizing multiple Kinects to be used by virtual try-on applications.

A key purpose of both virtual and real fitting rooms is giving the customer the look and feel of clothing of a specific size on the user's body, so the user can choose the appropriate size for him. Embedding the feature of matching clothing sizes with users requires capturing the users' body dimensions. More advanced frameworks even construct virtual avatars with input from only one depth sensor [22,23]. On the other hand, although these works provide higher detail avatars and more precise measurements, which might be more suitable for a made-to-measure type of framework, these processes require too much time to work with a real-time 'fixed-size try-on' virtual fitting room application, and we suggest that simple body height and shoulder width measurements are sufficient. These applications require a faster approach along with a specialized garment design framework such as the works of Yasseen et al. [24] or Meng et al. [13].

There are also notable studies for made-to-measure technologies for online clothing stores [25], shape control techniques for automatic resizing of apparel products [26], modeling a 3D garment on a 3D human model by 2D sketches [27], and garment pattern design using 3D body scan data [28]. Guan et al. [29] describe DRAPE, which is a learned model of clothing that facilitates dressing of 3D virtual humans of different body sizes and shapes with different postures. Their algorithm is composed of three stages: *shape and pose training*, *learning cloth deformation model*, and *virtual fitting*. Brouet et al. [30] present a fully automatic technique to transfer garments between characters with different body shapes in a design-preserving fashion. They formulate garment transfer as a constrained optimization problem and solve it using iterative quadratic minimization. A recent study [31] shows that such applications are well-received by public and have potential commercial uses.

3. The proposed approach

We expect that customized virtual avatars are going to have more significance in the near future in online interactions. To this end, in contrast with the previous work done in this area, our aim is to develop a system that is able to measure the user's dimensions in real time rather than offline and use the measurements to simulate the apparel on a virtual avatar rather than on the RGB image of the user. The results can be used in many applications, ranging from virtual fitting rooms in shopping malls to Massively Multiplayer Online Role-Playing Games with realistic avatars.

The main objective of a virtual dressing room is giving the user the idea of how an item of apparel will look on him/her without actually trying it on. As in any simulation, the absolute reality is almost impossible to attain, although with garment simulation and depth sensing technologies, a substantial level of realism can be achieved. The flow diagram of our framework is given in Fig. 1. The core components of the framework are the following:

- 3D scene rendering and render cycle management,
- weighted skinning and skeletal animation, and
- depth sensor integration.

Because these topics are considered as boiler plate for such an application, they are not explained in detail. We describe the embedded physics engine and explain its functions within the overall framework. We also explain in detail some of the features developed specifically for this particular application.

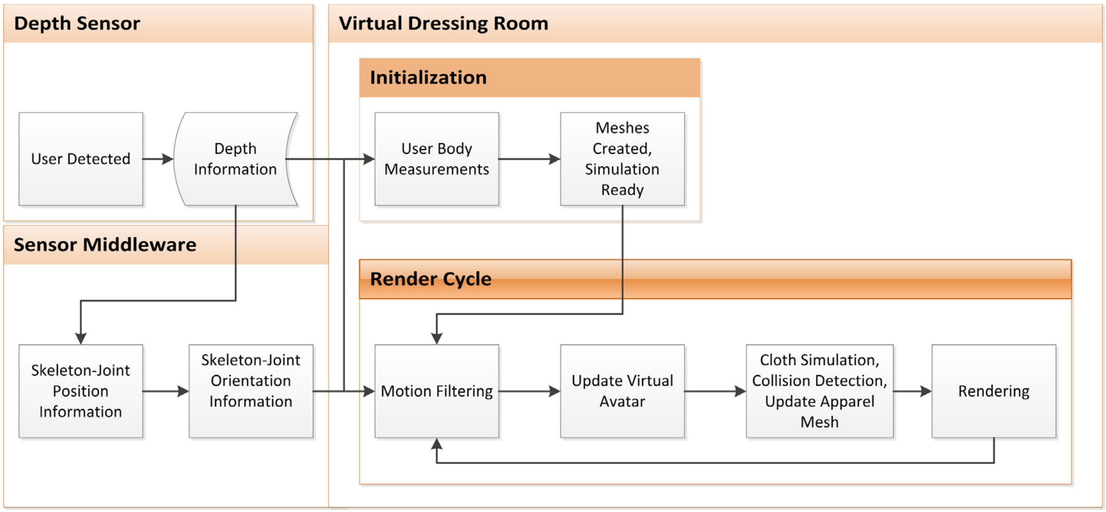

Fig. 1. The overall virtual dressing framework