DEVELOPMENT OF A KINEMATIC HUMAN MODEL FOR CLOTHING DESIGN / SIMULATION

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ABSTRACT

In recent years, there have been significant efforts directed towards the 3D product development of clothing on virtual human models. However, developers legitimately criticize that static human models are not suitable for the construction of sports, medical, and protective clothing. A garment that fits a static shape may be very uncomfortable while performing daily tasks including walking, sitting, or reaching. Without a realistic body shape and natural human postures, it is difficult to create properly fitting apparel. To improve wearing comfort and shorten development times, clothing must be designed based on specific body postures. Moreover, innovative knowledge about the interaction between body and garment during movement must be considered.

Key Words: Human model, 3D Scan, Animation, Simulation

1. INTRODUCTION

Presently available solutions for the assessment of wearing comfort during movement are based on virtual human models. However, currently, there is no human kinematic model for the display of realistic body deformations during movement, especially in the areas of elbow, knee, and hip joint. The resulting unrealistically deformed and partially penetrating surfaces do not allow for the creation of tight fitting garments in 3D. Especially when wearing functional and sports clothing, typical body positions strongly deviate from standard scanning postures. Hence, the generation of high-quality kinematic human models is of great importance in this research context.

In order to overcome the issues addressed above, an efficient and direct procedure for the development of realistic, personalized, kinematic virtual human models must be created, using only one 3D scan properly reflecting the anatomy of the human body. To achieve this aim, a template for skin, skeleton, and muscles is provided. A methodology for the application of the kinematic model onto individual scan data is developed, movement and specific body postures of human models are generated, and clothing test samples are designed as well as simulated on animated scans through the software *Clo3d*. Garment deformation is no longer investigated exclusively based on a static body shape, but also based on a wide variety of natural human poses and dynamic body deformations. Moreover, muscle deformation also influences the deformation of garments, which can be adopted as additional design element.

2. METHODS

In this research, we investigated the generation of individual, high-quality, kinematic human models, which can be integrated into digital process chains for the development of functional clothing. We present different techniques for automatically generating a personalized kinematic human model regarding speed, fidelity, compatibility, and software availability. Specifically, the following methods are compared:

- Linear blend skinning in simulation software *Clo3d* [1],
- Auto-rigging of 3D scan on online service *Maximo* [2],
- Skinned Multi-Person Linear (SMPL) [3] human model based on data and
- Anatomical simulation with plugin *Ziva dynamics* [4].

2.1 LINEAR BLEND SKINNING

The main advantage of Linear Blend Skinning (LBS) is the fact that it is not computationally intensive, yet still provides acceptable deformations in a good range of situations. Basic linear blend skinning models are the most widely used and are supported by most 3D simulation software solutions. In order to convert a body scan into an avatar adapted the body shape, the function named "convert to avatar" in the 3D simulation software *Clo3d* was employed (Fig. 1). Avatar joints are organically linked allowing for easier modification of poses. For the simulation, the basic construction of a pair of men's trousers and a T-shirt were selected (Fig. 2), and simulations were performed taking into account the mechanical material behavior. The strain map (Fig 2 b,c) is a geometrical measurement of the garment distortion/deformation. This presentation demonstrates how the pattern cuts deform while being worn. Thus, this serves as a good indicator as to whether fabric needs to be added to or removed from certain parts of the garment.

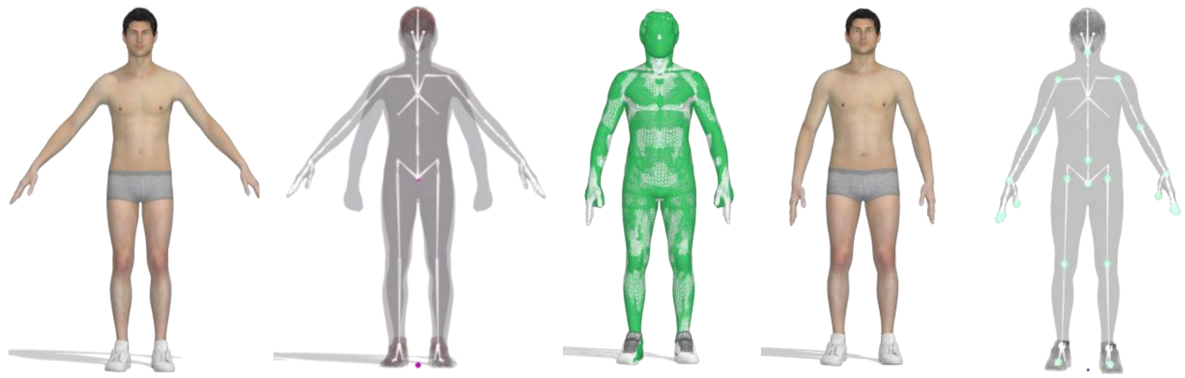

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Figure 1. Workflow of conversion to avatar: a. Clo avatar; b. align 3D body scan and Clo avatar; c. align avatar joints; d. converted avatar; e. 3D body scan with joints.

The same texture mapping blurs the geometric differences between the avatar and the scan (Fig 1a – *Clo3d* avatar, 1d – converted avatar).
However, there are also disadvantages to LBS. The body shapes are "approximated" by the adaptation of the scanning mesh to a standard mesh with significantly lower resolution. This mainly affects the volume loss in the joints, called the "candy wrapper effect", when bending and twisting. Unrealistic deformation in the areas of elbow, knee, and hip joint (Fig.2 d) cannot be overcome with this method.
So far, the fit assessment was primarily done in the standing position and while walking. Extreme positions, such as necessary when driving a car, were not assessed. As a result, fitting simulations for loose fitting garments on a converted *Clo3d* avatar are sufficient since extreme postures are neglected.

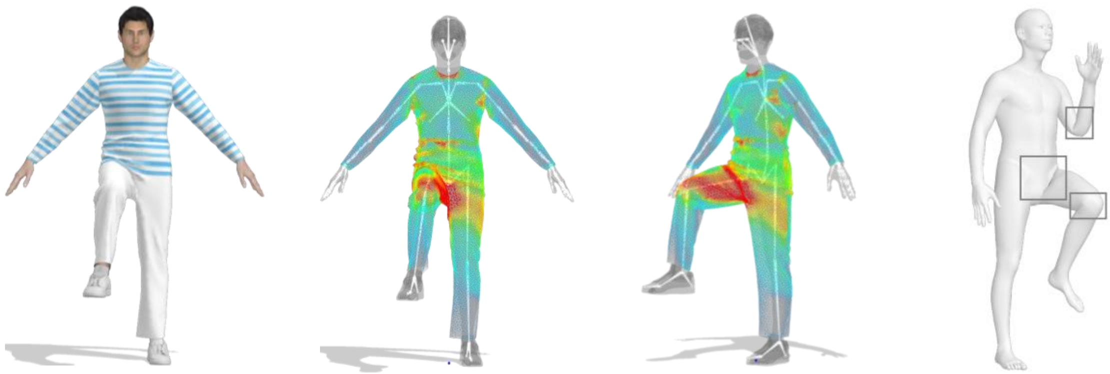

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Figure 2. Fitting simulation: a. individual avatar with bent leg; b,c. assessment of fit with strain map (frontal and right view); d. unrealistic deformation in the areas of elbow, knee, and hip joint

2.2 RIGGING 3D SCAN

In this section we would like to introduce a more accurate animation method that based on the use of the original scan data and requires very little 3D CAD or animation knowledge.

To show movements based on 3D scan data, we used the *Mixamo* auto-rigging online service, which calculates the skinning weights and inserts animation structures (joints, bones) into the 3D scan (Fig. 3). For this purpose, it is necessary to align the scan data exactly in the frontal plane and to mark the position of the joints interactively.

From a database, recorded movements (motion capture data) can be selected (walking, running).

These movements are transferred to the skeleton inserted into the scan data. This leads to a more realistic deformation of the body surface during movement. Figure 3f shows the improved deformation of the skin surface around the joints. Overlaps of the surface are not completely avoided (hip joint).To test the interaction between the animated model and the garment a fit simulation program, e.g. *Clo3d*, used. The model has to be imported in FBX format.

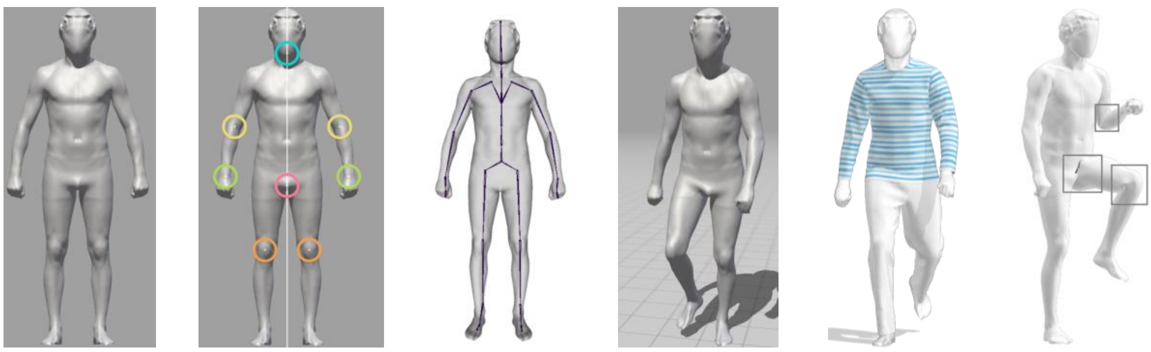

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Figure 3. Auto-rigging: a. 3D scan surface; b. place makers; c. insert skeleton structure; d.generation of animated 3D avatar; e. interaction between garment and body during movement; d. improved deformation in the areas of elbow, knee, and hip joint

2.3 DATA-DRIVEN SIMULATION

A good fit is difficult to achieve in fashionable apparel, but takes on a new dimension when it comes to functional apparel [5]. In order to achieve maximum performance in sports, the clothing is already constructed or virtually tested in sport typical positions.
Skinned Multi-Person Linear (SMPL) is a nearly realistic 3D model of the human body developed by Max Planck Institute. In addition, it is based on skinning, blend shapes and is learned from thousands of 3D body scans. Therefore, SMPL is able to collect and process the form deviation statistics among the test persons (KI) as well as to apply them to the individual personal data.

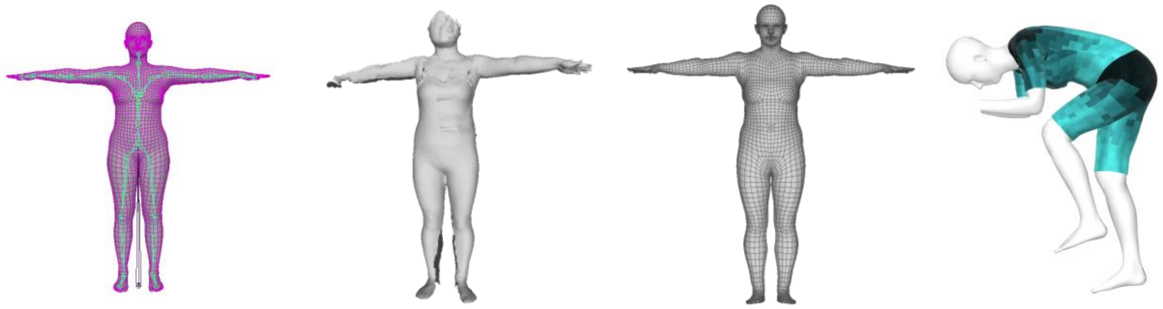

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Figure 4. Using SMPL human model to personalize 3D scans: a. SMPL human model; b. 3D scan; c.alignment of SMPL to 3D scan; d. construction cycling clothes in *Clo3d*.

These methods can capture the body shape of various people as well as non-rigid deformations due to different poses. However, data-driven methods use the same deformation model for all test subjects so they are limited in their extrapolation capabilities, an issue which can only be resolved by collecting even more data.

2.4 ANATOMICAL SIMULATION

For anatomical simulation, we used an anatomical model from the commercially available *Ziva dynamics*. This 3D anatomical model have used physics-based simulation. It provides a streamlined interface for simulating the breadth of anatomical tissues responsible for the physical appearance of a human body [4]. Comparing to data driving method physical simulation deliveries the advantage of building up person-specific bones and muscles (Fig 5 a,b,c), which will perform differently in animations [6]. Skin deformation is based on the underlying muscle, which will solve the problem in the areas of elbow, knee, and hip joint.

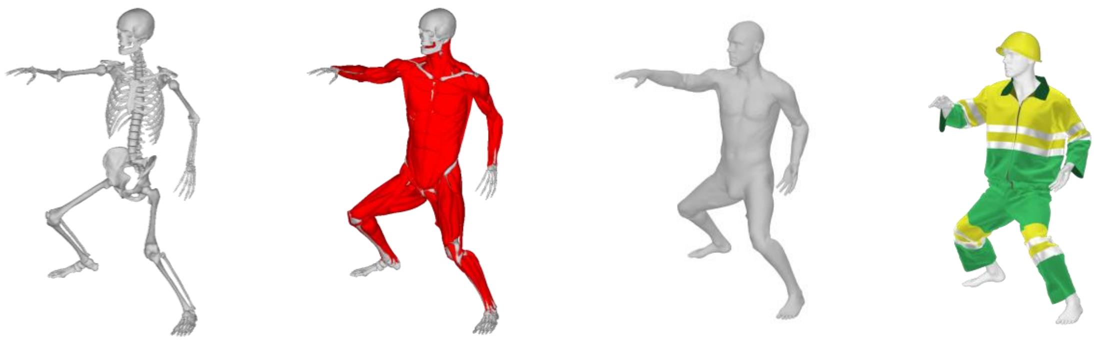

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Figure 5. physical simulation: a. bones; b. muscles; c. skin; d. simulation of functional clothing.

Regrettably, the construction of anatomically realistic avatar using person-specific scan is a labor- and computationally-intensive procedure and is very difficult to do for clothing experts.

Here we have tested this anatomical 3D model imported into Clo3d and constructed protective clothing on it. Muscle deformation also effects the deformation of garments, which can be selected as new design component. So a worker in protective clothing should be able to perform the constant movements with ease and always be dressed comfortably.

3. CONCLUSION

For the development of functional clothing, it is essential to be able to visualize these garments on individual human models and to be able to check the fit. For this purpose, kinematic human models are needed, which can be derived from scan data or generated anatomy-based. In this publication, various possibilities of model generation will be tested and evaluated concerning their applicability for close- or loose-fitting garments. Besides, a first assessment is made of the applicability of such models in the context of a virtual process chain for clothing development. The degree of detail and the procedure for creating the models vary greatly. Thus, it is necessary to define the requirements in advance of product development to select the right development methodology.

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