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3D garment fit on solid and soft digital avatars – preliminary results

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ABSTRACT

For a holistic assessment of the interaction between the human body and tight fitted clothing, it is necessary to consider the mechanical properties of the body. Default avatars in CAD software are usually solid and do not take this interaction into account. For this purpose, a solid avatar is converted to a deformable one by using the soft body physics implementation in the simulation program Blender. The fit of a 3D garment on both avatars are compared, which allows a first evaluation of the differences between these approaches.

1 Introduction

Conventional 3D garment simulations proof the fit to shorten the development time in the textile chain. Nevertheless, it must be considered that only stress and strain maps are being displayed here. Thus, only the stretch of the textile and the distance of the garment to the avatar are displayed. The fact that the pattern and the material itself can have an influence on the body by exerting contract pressure if the clothing is tight or compressive is not calculated in CAD programs for apparel. The main reason for this is that such simulations use avatars having the properties of a hard surface, whereas the mechanical properties of the human's body soft tissue is not taken into consideration. As a result, a change of the natural shape from the human body is not reflected in the simulation, but the textile will show a higher elongation during the fit check than would occur in reality [1].

In this study, a tight-fitting pattern was simulated on a solid and a soft avatar. For evaluation, the simulated avatars were then laid over each other in cross-section to identify the influence of the clothing on the body.

2 Mechanical behavior of the human body

Human tissue is an association of similar differentiated cells held together by intercellular contacts and the extracellular matrix. The basic tissue can be divided into four groups: epithelia tissue, connective and supporting tissue, nervous tissue and muscle tissue. Each of them has its own mechanical properties and there are different specific biomechanical textures within each group. The group of supporting and connective tissue is further divided into loose and tight collagen fibrous connective tissue, lipid tissue, cartilage and bone. The physical properties of the matrix of this tissue group are very diverse and consist of elastic fibers, collagen fibrils, adhesion proteins, glycosaminoglycans and proteoglycans. The muscle tissue group is divided into striated muscles, such as skeletal and cardiac muscles and smooth muscles [2]. Skeletal muscles are essentially incompressible and can be considered transversely isotropic due to the presence of a single muscle fiber direction. They are highly nonlinear with passive hyper elastic stress-strain relationships [3]. Lipid cells, also referred to as fat tissue cells, are also non-compressible and, when subjected to pressure from external forces, deform only as far as the reticular fibers allow and return to their original spherical shape when relieved of stress. From the technical clothing point of view, human bodies are assigned to garment sizes by determining the length and girth measurements of the body, but individual histological differences have a significant influence on the deformability of the bodies' tissue. The ratio between a person's body fat and muscle percentage is a decisive factor for the individual elasticity of the soft tissue on which the textile exerts contact pressure [2,4]. As an example, the nonlinear viscoelastic, anisotropic and incompressible mechanical behaviour in deformation of a muscle can be precisely described by using Ogden's hyper elastic model for virtual replication [5].

There are several ways for measuring the mechanical properties of the human soft tissue. The tissue material can be tested by determining the tensile strength, elongation, elasticity, Young's modulus and bending stiffness. These parameters need to be determined for the digital remodeling of the tissue [4]. However, a test method needs to be carried out for each type of tissue and it must be considered that these values only reflect the individual properties of the test subject. Several studies model body parts in a simplified way based on 3D scans and magnetic resonance imaging to identify the present tissue zones in the body part. In this study, the bones are modelled as rigid bodies and soft tissue is summarily modelled as linearly elastic, homogeneous and isotropic, thus directionally dependent [1]. Another example is the FEM human model HUByx from Altair which is also based on the geometry of the organs and the skeleton from CT scans provided with the material behavior excerpted from literature. This FE-model has been developed for ballistics and simulates all bones, organs and the internal fluid among these, in order to simulate the ballistic impact especially for the torso [6]. A different approach to detect tissues softness for simulations is to conduct by a standardized detection of yielding by applying contact pressure through a device designed for this purpose. Examples for this are the so-named 'Tissue Elastomer' [7] or the technology from VitalFit, which is able to capture the properties in vivo. The recording of the mechanical properties of soft tissue in vivo is a special case, since the so-called method of poking can otherwise only be carried out with tissue samples taken from a test subject ex vivo [8]. Furthermore, 4D scanning and motion tracking are methods for recording possible movements of the body tissue. These methods combined are able to capture the deformations of the body in motion or while wearing tight-fitted garments in comparison to the static image or natural shape of the test subject. This approach originates from the field of animation, where realistic dynamic body shapes can be simulated based on a second-order auto-regressive model that predicts soft-tissue deformations learned from previous deformations [9]. In order to simulate the deformation behavior of the soft tissue influenced by tight-fitting clothes, the modelling based on CT scans is the most practical and a non-invasive method for generating a soft avatar and enables the exact determination of the geometry for the different tissue structures inside [10].

3 Garment fitting

Tight-fitting and compressive garments can change the natural shape of the body due to the contact pressure they exert. This results from an interaction of the material parameters of the textile used and the pattern of the garment. The interaction between the wearer and the textile is not only influenced by the mechanical properties of the different used fabrics, but also by the specific properties of the wearer's body as they define the resulting fit, which is finally decisive for the functionality of the garment. Tight-fitting garments can have properties such as being supportive, shaping or compressive, and are often used in the medical sector [1].

Conventional garment CAD programs do not have soft body simulation capabilities. To simulate deformable objects like soft tissue, they can for example be modified with soft body physics in Blender to show forces acting on them. The forces are divided into exterior and interior ones, the latter holding the vertices of the object together. The exterior forces, e.g. gravity acting on the soft body object, are applied to the vertices by using Newton's law of physics for a particle spring-mass model. In the settings the stiffness and the damping of the springs can be adjusted. The springs can have a specific stiffness value for a vertex group and can include shearing. The pull setting determines the spring stiffness for edges and thus specifies how much the edges of the object's section are allowed to stretch. The more elastic the material, the smaller the pull value, whereas the stiffer the material, the higher the pull value. Push is set to describe the ability of the springs to be compressed. The modification damp is used for friction of edge springs. Furthermore, the plasticity can be set if there is a permanent deformation of the object after a collision. The bending according to Hooke's law for springs connects vertex and vertices with adjacent edges including the diagonal edges under consideration of the damping. The length setting describes the percentage of shortening or expansion and it is also possible to simulate a collision of the edges of the soft body mesh [11]. To apply these soft body physic modifiers to mechanics, it is necessary to consider biology, so biomechanics need to be translated with Blender's modifications to describe the tissues continuums mechanics of physiology in e.g. elasticity and deformability [12].

4 Materials

The leggings pattern was produced by flattening it directly from the solid avatar's body shape and applying a 20% reduction in width. Both clothing pattern are taken over the UV surface, as shown in Figure 1.

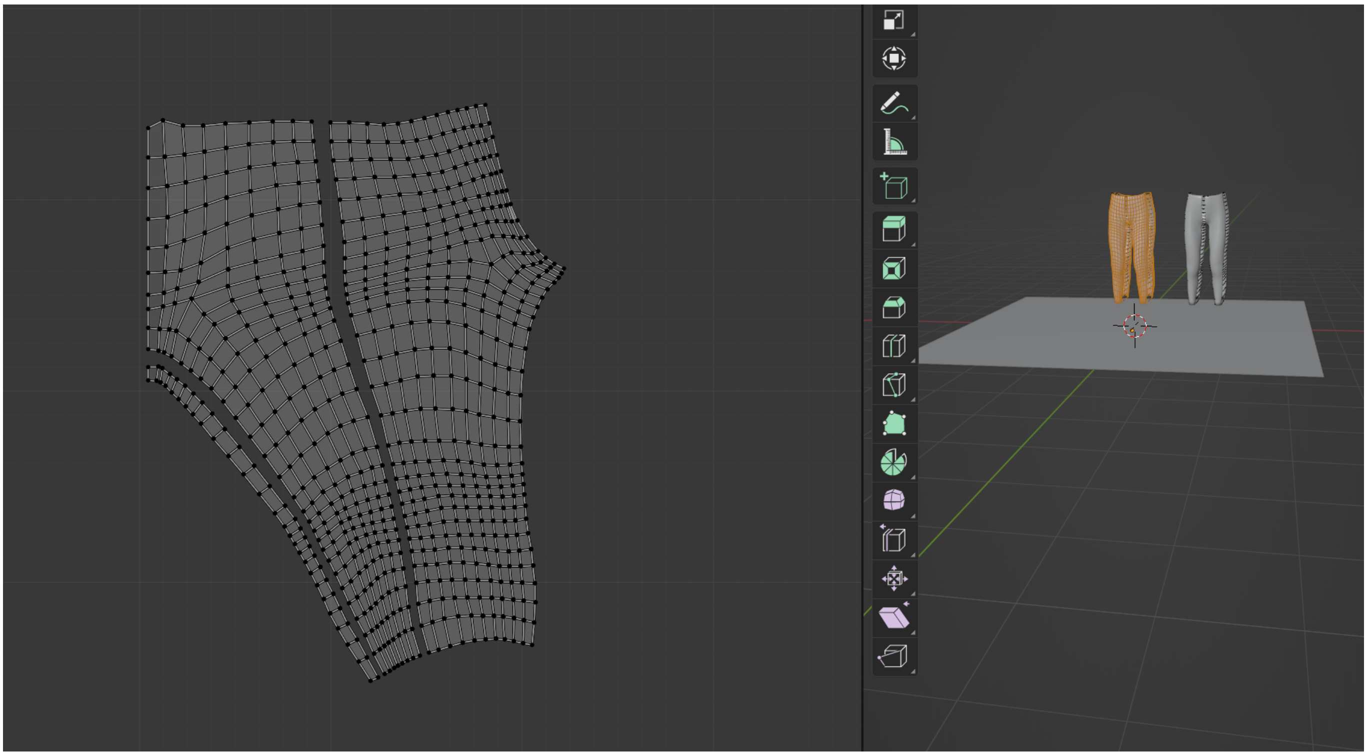

Fig. 1 Pattern pants in Blender.

To identify the differences, the pattern's fit of the tight fitted pants was simulated in the conventional way on an avatar with a solid surface and also on an avatar with soft body physics. In order for the material to stretch around the body despite the negative ease, it must be highly elastic. The material and simulation settings of the cloth and soft body physics modifier have been set for this purpose as listed in Table 1:

Table 1. Blender cloth modifier material and soft body physics settings, most Blender values are dimensionless

Cloth modifier settings			
Simulation		Quality Steps	10
		Speed Multiplier	1.000
Physical Properties		Vertex Mass	0.3 kg
		Air Viscosity	1.000
		Bending Model	Angular
	Stiffness	Tension	15.000
		Compression	15.000
		Shear	5.000
		Bending	0.500
	Damping	Tension	5.000
		Compression	5.000
		Shear	5.000
		Bending	0.500
Shape	Sewing	Max Sewing Force	65.000
		Shrinking Factor	0.002
Collision		Quality	8
	Object Collision	Distance	0.01
	Self Collision	Friction	5.000
		Distance	0.015
Soft body physics modifier settings			
Object		Friction	0.500
		Mass	1 kg
Goal (on vertex group)	Settings	Stiffness	0.500
		Damping	0.35
Edges		Pull	0.8
		Push	0.8
		Damp	20.000
		Plasticity	0
		Bending	5.000
Self-Collision		Calculation Type	Angular
		Ball Size	1.55
		Stiffness	1
		Dampening	0.500
Field Weights		Gravity	1

5 Cross section comparison

The flattened pants have the exact same measurements and material parameters for the simulation, and the visualization (Fig. 2) clearly shows that the simulations present different fit results. On the left, the leggings on the avatar with the hard surface have lager seam gaps, whereas on the right, on the avatar modified with soft body physics, the leggings cover the body better. In addition, the leggings wrap around the soft tissue body faster than around the solid avatar, the calculation takes 27 frames whereas it takes 138 frames for the leggings to be simulated on the solid avatar. From this it can be hypothesized that the material needs to stretch more for the fit check on the avatar with the unyielding surface.

However, it can also be seen that the seams of both leggings are gapping, which is caused by the simulation in Blender, as seams are created by defining edges as those and then pulling them together only at the vertices there. The finer the mesh of the garment, the finer the seam simulation.

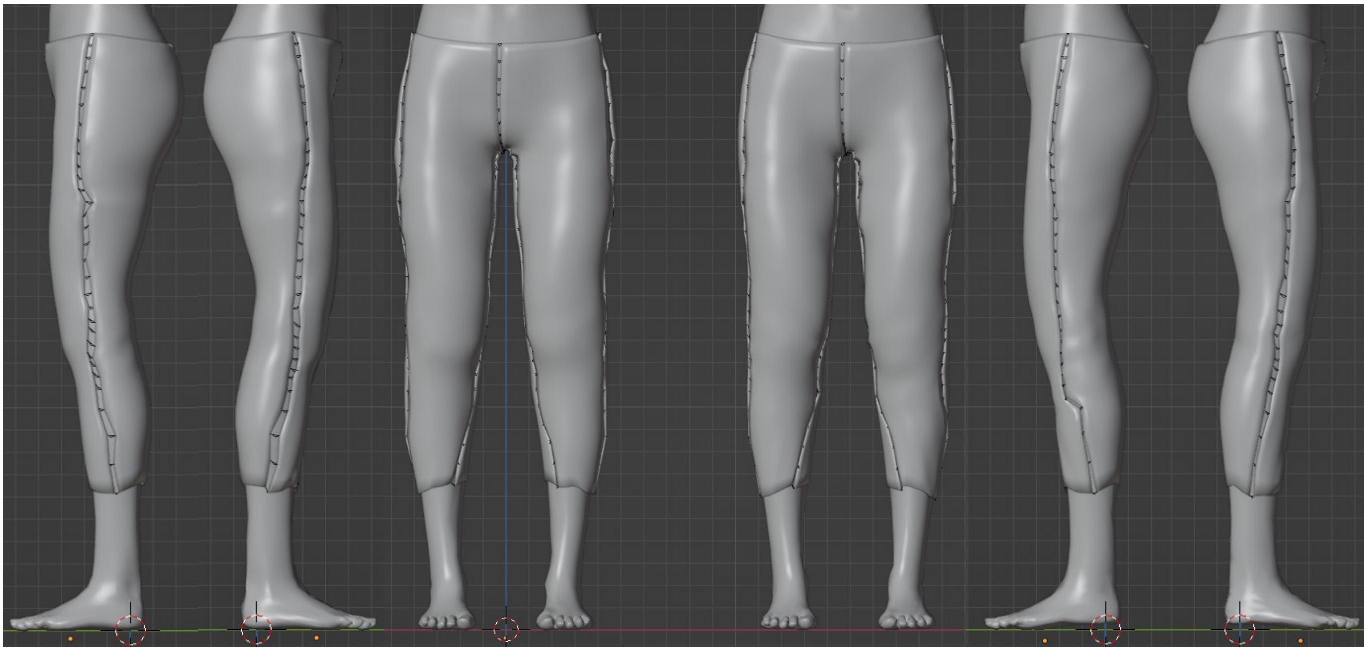

Fig. 2 Simulated pants, (left) solid and (right) soft avatar.

Examining the simulated pattern in cross-sections when the avatars are hidden, it is clearly visible that the contour lines are differentiating, as can be seen in the cross section of the hip (Fig. 3).

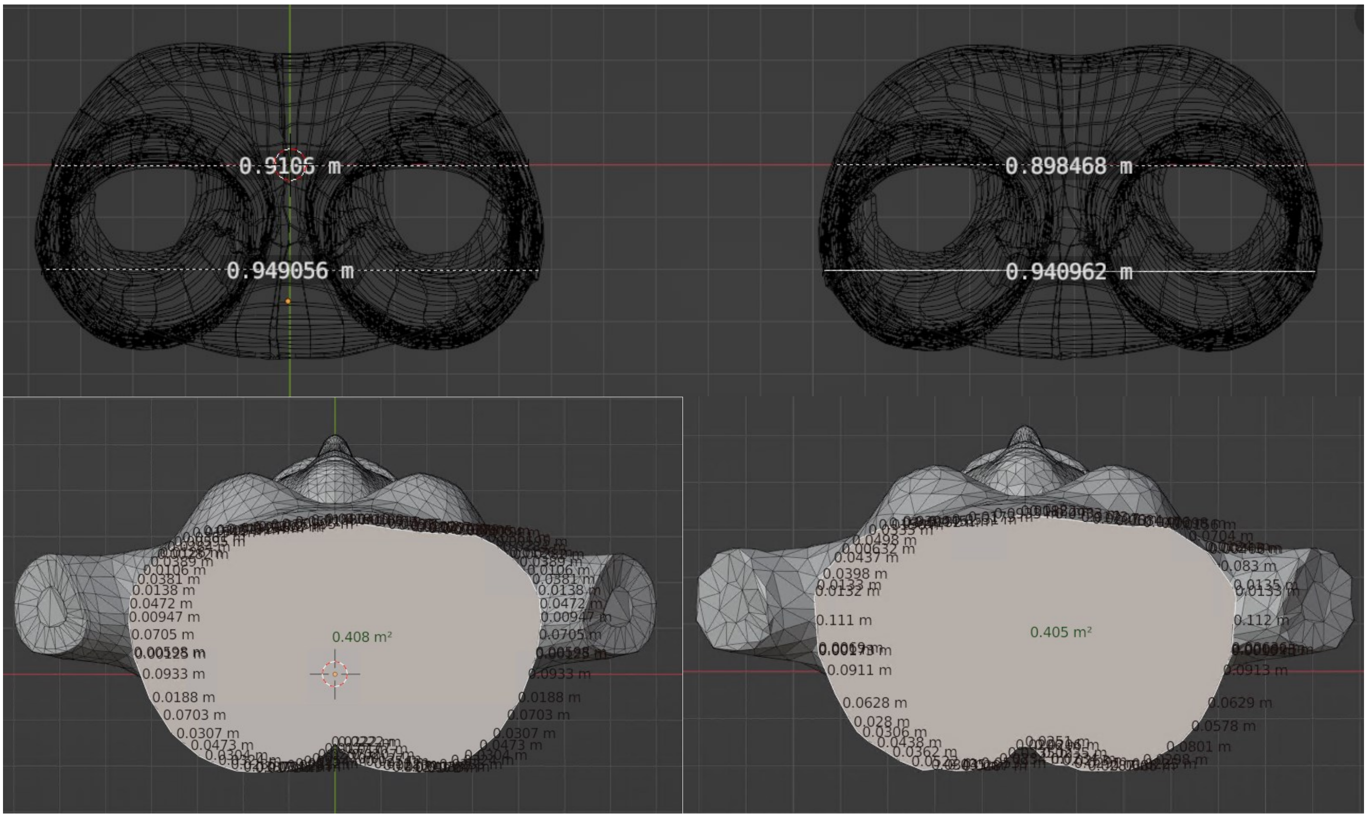

Fig. 3 Cross section hip width and girth

The diameter of the two calculated patterns was determined at two reproducible locations in top orthographic view. The hip girth has been measured in bottom orthographic view, the difference is shown in percentage in Table 2.

Table 1. Differences in diameter of the simulations.

	Pants on solid avatar (mm)	**Pants on soft avatar** (mm)	**Difference** (mm)	**Difference** (%)
upper	910	898	12	1.35
lower	949	940	9	0.86
	Solid Avatar (cm)	**Soft Avatar** (cm)	**Difference** (cm)	**Difference** (%)
Hip girth (cm)	90.204	89.69	0.514	0.573

To visualize the different fit results, the simulated pants on the different avatars were exported as a point cloud. The two files were then layered in the program CloudCompare in different colors. It is clear that the pants calculated on the avatar with the hard and unyielding surface are for the most parts outside the pants calculated on the avatar modified with soft body physics. Figure 4 shows in blue the pants that stretched further for the simulation and in green the leggings whose material parameters and pattern is able to influence the soft avatar.

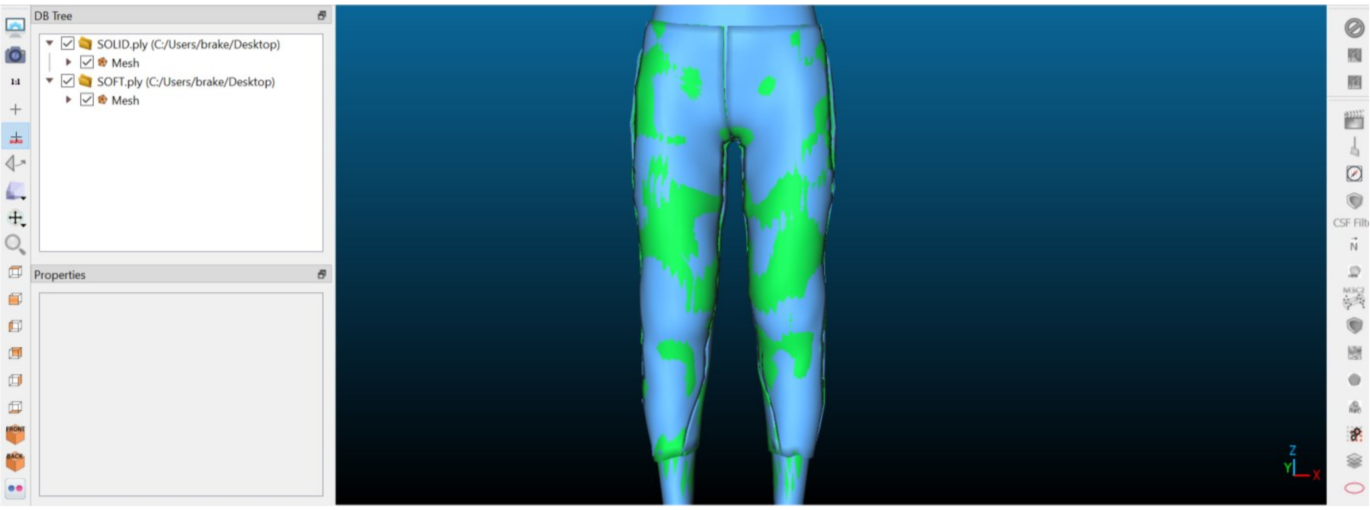

Fig. 4. CloudCompare fit comparison between the form on solid and soft avatar

6 Conclusions

The simulations of the pants on the avatar with the solid surface on the one hand and on an avatar with soft body physics on the other hand show that the material must stretch further in the former case: 1.3% at the upper recorded point at the hip of the solid avatar and 0.8% at the hip's lower point. Furthermore, the calculated hip girth of the soft avatar shows a difference of 0.57% less than the girth of the solid surface avatar. Therefore, it can be assumed that the simulation of patterns on an avatar containing soft body physics gives a better result than the fit of the pattern simulated in the traditional way on a solid avatar.

But even if the soft tissue parameters can be applied to the avatar, the modification possibilities in Blender for a complete adjustment of the physical properties of the human body are not transferable to the physical values. This is due to the fact that for example the values for the Young's modulus or the Poisson's ratio can only be entered between 0-0.999 and are dimensionless instead of being based on the units of the physics of mechanics. This would then also include a controlling process that enables the material model of soft tissue to ensure the tissue's ability to be incompressible. Furthermore, different tissue zones have different mechanical properties, which makes it indispensable to identify and classify these zones and apply a method for testing and capturing softness for translation into the software to model a soft avatar. Therefor it is required to model the avatar with the soft body physics according to the geometry of the different zones. In further investigations, it is therefore necessary to embed and verify the mechanical values in the soft body physics, so that a correct simulation can be achieved.

Author Contributions

Elena Brake – simulation, draft preparation; Y. Kyosev and K. Rose: supervision, review and editing, project administration. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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