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Is this real? Avatar Generation for 3D Garment Simulation

Anke Klepser* and Christian Pirch
Clothing Technology Research & Technology, Institute for Textile Innovation, Hohenstein Group
Boennigheim, Germany
*Corresponding author, email: a.klepser@hohenstein.com

ABSTRACT

In the last decade, technological development of 3D garment simulation software has accelerated. Garment simulation is widely discussed in industry and research. The advantages are significant. Fewer physically sewn prototypes are needed, saving time and money. It facilitates faster, better communication, which leads to quicker decisions within the development process. Fit models can be made available in all sizes, making simulation across the entire size range possible. Yet, the quality of the garment fit evaluation depends on accurately sized avatars and realistic fabric drape combined with deep understanding of the software's simulation process and expertise in garment engineering. But default avatars have limitations. For example, moving limbs show unrealistic "water hose effects" of joints where the tube-like arm or leg is simply folded. This study's aim was to three-dimensionally compare software-provided avatars with 4D scans of real test persons. In addition, a new process for avatar generation was developed outside of 3D garment simulation software. The results are parametric and rigged avatars to be utilized across the platforms.

Keywords: 3D Body Scanning, 3D Garment Simulation, Avatar Generation, 4D Body Scanning, Digital fit models

1. Introduction

The use of 3D garment simulation software has been of scientific interest since the 1980s. Initial hurdles included setup costs, user expertise, technology limitations, and accurate fabric simulation (Power, 2013). Garment simulation was mostly performed by enthusiasts and visionaries. In the last decade, technological development has accelerated and various 3D systems are now readily available on the market. Garment simulation is now widely discussed in industry and research. (Jevšnik, Stjepanovič, & Rudolf, 2017; Lapkovska & Dabolina, 2018; J. Lee, Nam, Cui, Choi, & Choi, 2007; Song & Ashdown, 2015). More and more companies are already utilizing simulation software in their processes. Others are in the decision-making process. Before adoption and implementation, important questions must be answered, such as: how can 3D garment simulation be integrated into the current development process? Which program is most suitable? Is the aim visualization, fit assessment or both? Are current employees already capable of performing simulations or do they need training or additional expertise? And above all: is the outcome reliable?

The advantages of 3D garment simulation are significant, especially because fewer physically-sewn prototypes are needed (H. Daanen & Hong, 2008; Ernst, 2009; Istook Cynthia & Hwang, 2001; Krzywinski & Siegmund, 2017; Morlock, 2020b; Sayem, 2019). As Song and Ashdown (2015) point out, these tools decrease the average number of prototypes from between three and five samples to two, while cutting the total amount of time by an estimated 50%. Digital visualization and prototyping also facilitates faster and better communication within or between working groups of differing backgrounds, such as designers, engineers, marketers, and managers (Morlock, 2020a; Song & Ashdown, 2015). Adaptions like color, pocket position, and most significantly, pattern adjustments, can be made in seconds. This leads to quicker decisions within the development process. At the same time, digital products can be used for marketing and online shops (Sayem, 2015).

For technical development, fit models can be created in all sizes for simulation across the whole size range (Morlock & Keinath, 2019). However, the quality of the garment fit evaluation depends on accurately sized avatars and realistic fabric drape (Sayem, 2019) combined with a deep understanding of the software's simulation processes as well as garment engineering know-how.

Whereas 3D garment modeling and virtual fabric drape have been widely investigated, there was no comprehensive focus on the default, software system avatars. This study's aim was to three-dimensionally compare software-provided avatars with 4D scans of real test persons. In addition, a new process was developed for avatar generation outside of the 3D garment simulation software. The results are parametric and rigged avatars to be utilized across the platforms.

2. Review of literature

Commercially available 3D applications for garment visualization or prototyping include Vidya by Assyst, CLO 3D by CLO Virtual Fashion, VStitcher by Gerber Scientific (Assyst GmbH; Browzwear Solutions Pte Ltd; CLO Virtual Fashion LLC), and many others. Garment simulation is commonly performed in four steps. First, the system default avatar is chosen or adapted according to defined body measurements. Alternatively, an individual 3D body scan or a generated avatar is imported into the system. Second, the textile material properties are implemented. Third, the pattern pieces are assembled at the seams and digitally stitched together. Forth, the garment is placed and draped on the avatar (Song & Ashdown, 2015).

3D garment simulation software can be used for visualization, fit assessment, and many applications in between. Three pillars form the foundation for each process: garment patterns, textile materials and avatars. Each goal has its own path. Visualization aims to present the idealized product in the most appealing way. The material parameters of the garment and body shape of the avatar can be adjusted for a perfect optical result. For virtual try-on processes, realistic factors are crucial. The physical parameters of the materials need to be tested precisely and translated for the 3D software. Avatars must be accurately adjusted according to the body measurement charts. As in real fit testing, garments should be assessed in typical user poses (Ashdown, 2011). The aim is to assess shape and proportion of the product, to identify fit problems and to solve them. Successful virtual fitting processes utilize a combination of 3D technology and traditional fit and pattern expertise (Morlock, 2020c).

Various approaches to research of 3D garment simulation were reviewed. Most research has focused on the garment itself. Products were 3D modeled and unwrapped into 2D, 2D patterns were 3D simulated, and fabric drape was widely discussed. Most concepts are of scientific interest and provided useful resources for software developers, but did not address the end-users and designers (Sayem, 2015).

The effectiveness and accuracy of current technology has been investigated by several researchers. These studies compared the virtual and actual fit of skirts (Lapkovska & Dabolina, 2018; M. Lee, Sohn, & Kim, 2011), shirts (Sayem, 2017), and pants (Kim & LaBat, 2013; J. Lee et al., 2007; Song & Ashdown, 2015), among others (Ögülmüs, Üreyen, & Arslan, 2015; Porterfield & Lamar, 2017). They focused on the fabric draping by considering fabric properties, such as bending, stretching, weight, smoothness, etc. (Balach, Cichocka, Frydrych, & Kinsella, 2020; Power, 2013). They also investigated similarities or differences between real and virtual garment fit based on fit locations, body shapes and overall fit status (E. Lee & Park, 2017; Song & Ashdown, 2015). Fabric can be adjusted by entering textile-physical properties. Yet, each simulation system requires different values in varying units. In addition, software systems are not transparent on how they utilize the material properties (Sayem, 2020).

Whereas fabric drape was investigated by various researchers, avatars were barely considered. Sayem et al. (2019) investigated how the software's default avatars can be adjusted to intended sizes and validated how realistic the output was. The study points out that "*none of the systems is free from limitations.*" Analyzing avatars reveals differences between software in the appearance and shape. Daanen et al. (2018) emphasized that the existing models are poorly validated. According to Sayem (2020) and confirmed by Balach (et al., 2020), the default avatars are anthropometrically and anatomically incorrect. This is even more visible in dynamic fit testing. For example, moving limbs show unrealistic "water hose effects" for joints where the tube-like arm or leg is simply folded. The complex bone-muscle-surface interaction is not correctly performed. However, testing fit during movement is important for all apparel, especially sports- and workwear. As the body surface changes with movement, the body dimensions change. This can lead to fit problems, mobility restrictions, reduced performance, or limited protection for the garment user (Klepser, Morlock, Loercher, & Schenk, 2020).

This study had two specific objectives. First: identify the accuracy of default avatars in 3D garment simulation software by comparing them to 4D scanned body geometry. Second: develop a process to generate rigged avatars for analyzing fit in motion.

3. Methodology

The test person sample included 9 male subjects aged 28 to 59 with an average body height of 184.8 cm, correlating to the German sizes 50, 54 and 58 (chest girth 100 cm, 108 cm and 116 cm, three subjects in each size). The subjects were scanned in three poses or movements: relaxed, half T-pose and 90-degree flexion in hip and knee joint of the right leg (see Figure 1). 3D full body scanners "Vitus Smart XXL" and "little Alice" were utilized. The laser scanner "Vitus Smart XXL" was used to scan the relaxed position as a reference and as the basis to take body measurements. The movements "half T-pose" and "90-degree leg flex" were scanned with "little Alice" photogrammetry scanner.

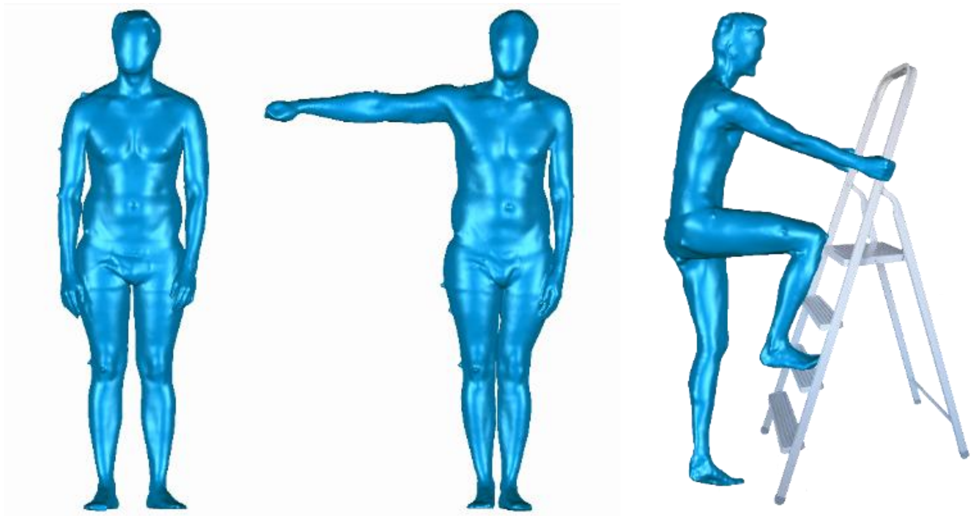

Figure 1: Scan positions: relaxed, “half T-pose” and “90-degree leg flex”

Movements were defined by a starting position, the movement and an end position as presented in Table 1. They were demonstrated to the test subjects and described verbally. Figure 2 shows an example of the of the “leg flex” movement with the start position on the left, the movement in the middle and the end pose on the right.

Table 1: Definition of movements

Name	Starting position	Movement	End position
Half T-pose	Legs hip wide, both arms relaxed at the side of the body	Stretched right arm is moved on frontal plane up to shoulder level	Right arm is stretched on shoulder level lateral
90-degree leg flex	Legs hip wide, both arms relaxed, hands on the ladder	Right leg lifted up to a hip flexion of 90-degrees and a knee flexion of 90-degrees, right foot is positioned on second step of ladder	Both feet are located on second step of ladder

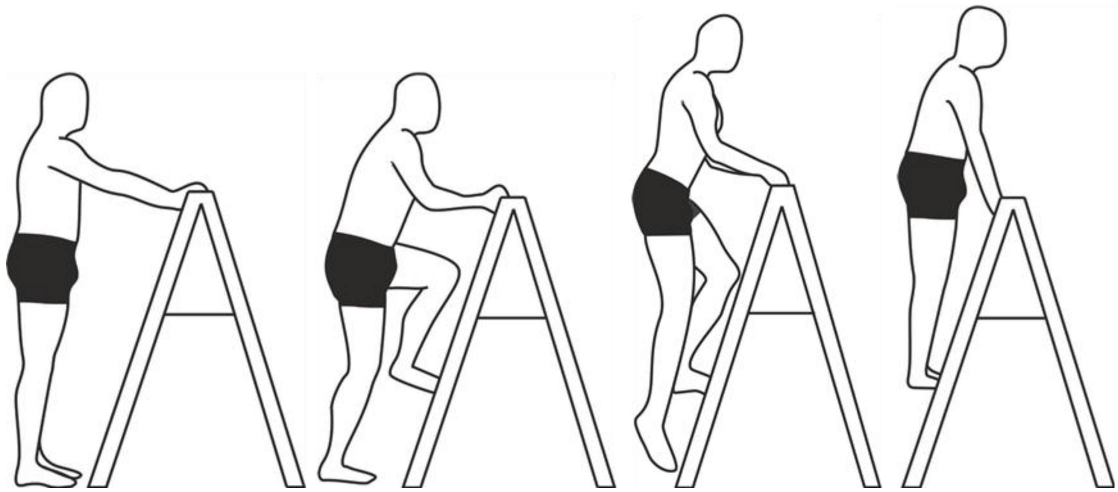

Figure 2: Movement series "leg flex" from starting position (left) through end position (right).

Body measurements (body height, chest girth, waist girth, hip girth, etc) were taken from the relaxed scan. 3D data was post-processed to enable detailed shape comparisons. Avatars from three 3D garment simulation software systems (CLO 3D, VStitcher, Vidya) were adapted according to individual body measurements and half T-pose, arm flex and hip/knee flexion was performed for each (Assyst GmbH, Browzwear Solutions Pte Ltd, CLO Virtual Fashion LLC). 3D analyses used Geomagic Studio software (3D Systems Inc.) were performed to compare the scans with the system avatars in equivalent poses.

A new process for avatar generation using Blender 3D (Blender Foundation) was developed. The starting point is a basic mesh placed on the scanned bodies with the help of predefined markers. After positioning, the vertices of the basic mesh are projected onto the scanned body. After the process of projection, where the mesh has irregular edge lengths, these have to be made uniform again. The base mesh is rigged and can therefore be adjusted to defined positions by rotating the bones. The main circumferential lines are stored as texture on the surface so that the changing surface area can be optically detected. The weights of the vertices are adjusted after the rotation of the bones based on the scan. Areas such as armpits or popliteal fossa (knee pits), which are difficult or impossible to determine with the vertex weights, are adjusted using the scan. The points in the critical areas are projected onto the scan and thus represent a realistic surface. The flexion of the muscles is stored as a "shape key" that is activated during the defined rotation of the bone. Shape keys are modifications of the original mesh that can be stored within the object.

4. Results and discussions

For a reliable and valid virtual fit assessment, two factors must be correct: the material performance and the avatar geometry. So far, avatar shapes in 3D simulation software have shown limitations, especially in movement. Therefore, this study had two aims. In the first step, the accuracy of default avatars from 3D garment simulation systems was identified by comparison to 4D scan body geometry. In the second step, a new avatar generation process was developed. The result is rigged avatars for fit in motion analysis with more realistic body geometry. 4D scans were used to optimize the mesh on the new avatars.

The current state of simulation software was analyzed by comparing scanned test subjects with adjusted avatars. Figure 3 shows one scanned test subject in size 50 (chest girth 100cm) on the left and the corresponding avatar with adjusted measurements on the right.

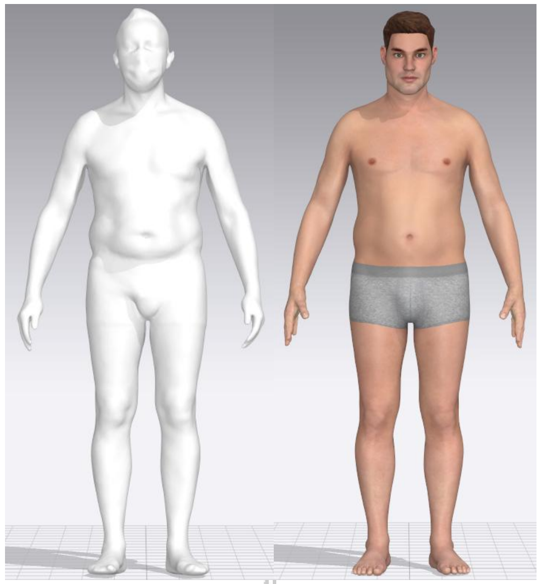

Figure 3: Scan of test subject (left) avatar from simulation software (right), both in relaxed pose

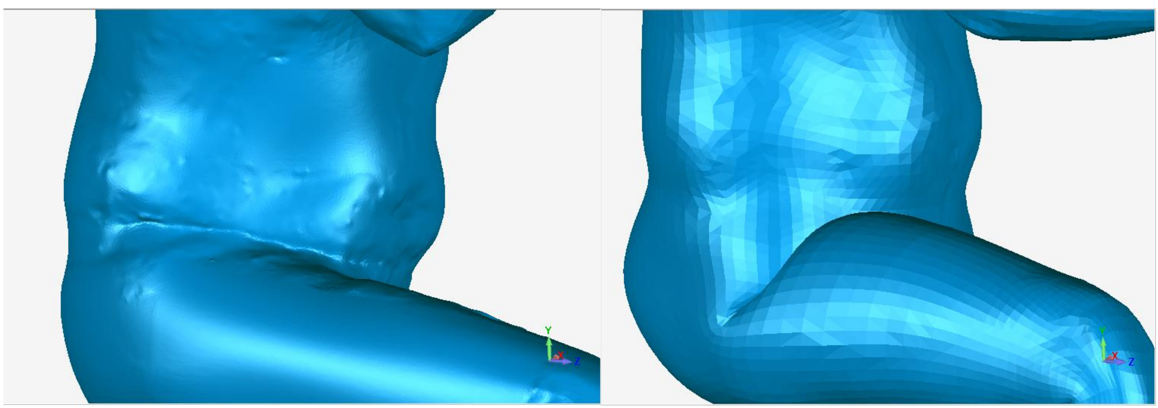

Figure 4: Scan of test subject (left) avatar of simulation software (right), both in leg flex pose

Comparing the system avatars to the scans revealed significant differences in body shape. Clear differences were revealed in how parametric avatar creation works in various 3D simulation software. In addition, not all sizes and body shapes can be automatically created. Adjusting avatars with body measurements sometimes leads to inaccurate shape results. Two-dimensional body measurements influence but cannot describe the three-dimensional body shape.

Findings show that avatars in motion still demonstrate the water hose effect at the joints (shoulder, hip, knee etc.) where the surface overlaps at a certain point. At these points, the tissue should compress and change its cross-section. From the left, Figure 4 shows the scan of the test subject performing the leg flex pose and the corresponding avatar from 3D simulation software. The avatar reveals an unrealistic fold at the hip joint. Because software-generated avatars do not simulate soft tissue, body areas that are compressed or reshaped by movement or garment cannot be presented in a realistic way.

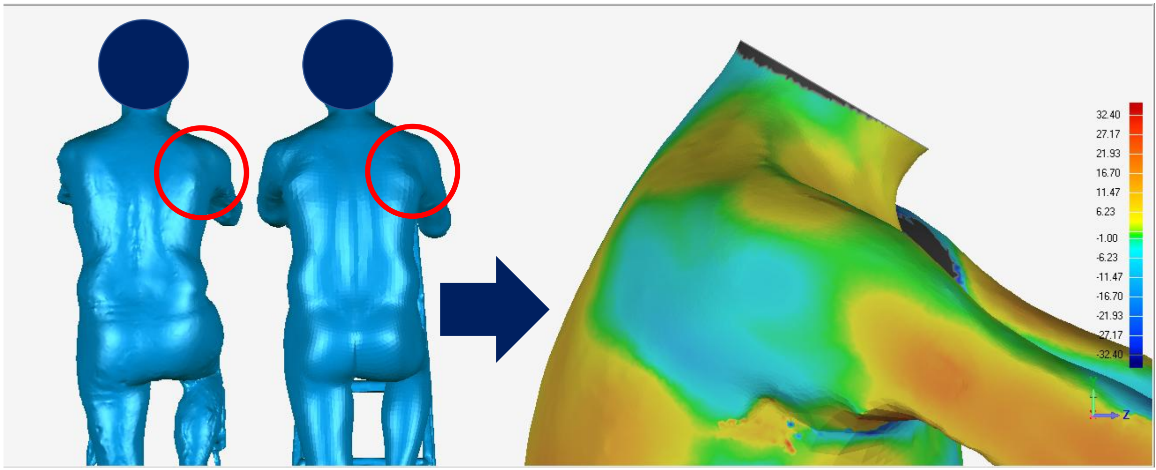

Figure 5: Scan of test subject (left) avatar from simulation software (middle) both in leg flex pose; 3D analysis (right)

The 3D analysis was conducted by merging the human scan (left) and the default avatar (middle). The comparison in Figure 5 reveals differences in the shoulder area. Inconsistencies in geometry were visualized through color with the reference scan as the basis for the “heat map” (right). Where green represents areas that are similar, yellow, orange, and red show expansion of geometry, or areas where the body of the avatar is bigger than the scan. Blue represents areas of reduction, where the avatar geometry is smaller than the scan. The shoulder areas showed reduction of more than 1 cm (2.54 in). Furthermore, it is possible to rotate and move the joints of the default system avatars over all axes without restriction, a range of motion is not considered here.

Comparing moving avatars from different software systems shows varying quality of mesh geometry. For avatars from three software systems, Figure 6 indicates areas where the mesh is compressed in green and stretched in red. The most obvious differences are in sizes of the areas affected by the movement. In the left two images, the kink in the shoulder clearly reveals where the surface transformation point is positioned. In all three default avatars, the armpit is not sufficiently represented.

Musculus latissimus dorsi is one of the back muscles that is responsible for the abduction of the arm. This muscle moves the arm away from the torso and up on shoulder level. Therefore, it is visible on the side of the torso of athletic subjects. This characteristic is only demonstrated by the last avatar on the right.

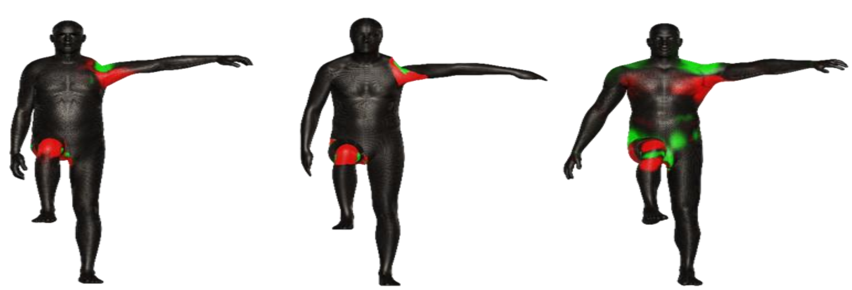

Figure 6: Avatars from three different 3D simulation software systems, in combined half T-pose and 90-degree leg flex pose

The 4D scans of movement were taken as a starting point for a new avatar generation process. The scanned geometry serves as a basis and represents the reality. Figure 7 shows that the armpit simulation with conventional rigging (orange) no longer works when the arm is lifted. Using the 4D scan (black) as a foundation for mesh creation, the accuracy was improved enormously, as can be seen in Figure 8. The mesh of the avatar was aligned with the 4D scan in the defined pose.

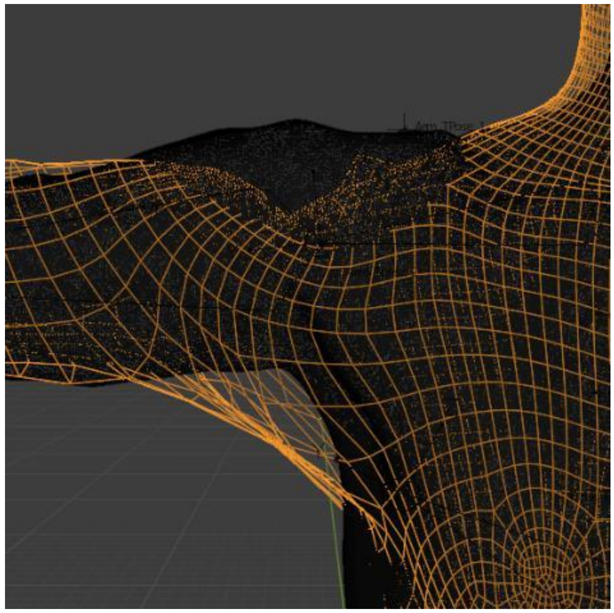

Figure 7: Difference between scan and a normal rigged avatar

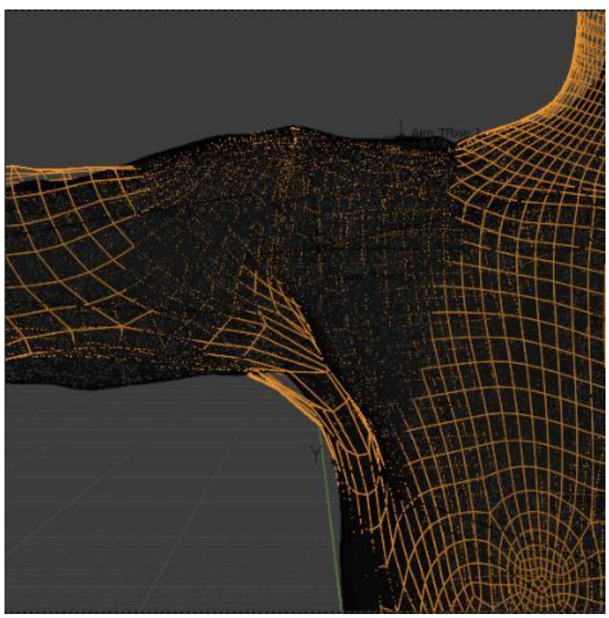

Figure 8: Area aligned with scan data

Body surface areas were individually connected to bones in order to avoid malformations. Dimensional dependencies, as represented in 3D simulation software, can be variably set. Finally, rotation limitations were set to create a natural range of motion. The combination of correct range of motion and optimized mapping of body surface and bones led to accurate shaping results in movement.

The current disadvantage of this newly developed method is the time-consuming requirement for manual surface adjustment. In the next steps, further digital poses will be compared with 4D scans. The aim is to define which zones of the grid are poorly represented by conventional rigging. This way, a clear correlation can be shown between the bones of the rig and the problematic zones. In contrast to many digitally generated motions, this method uses human scans for higher correlation to the real movement. Unfortunately, the method cannot be used for areas of geometric overlap caused by bending of bones, since this overlap cannot be recorded with a scanner.

The potential to automate this method is high. For example, identifying the body zones and dividing them into vertex groups, aligning the rigged avatar's bones with the scan geometry, calculating the distance to the scan, and creating shape keys can all be automated.

5. Conclusions

Virtual fit assessment is the future of garment development. For some companies, it is already a reality. The time and cost savings from digital processes are significant. To improve the quality of the garment, it is important to analyze the fit of the garment not only in the standard pose, but also in typical movements of the target group or intended application. Therefore, reliable avatar libraries with complete size sets are needed. The newly developed avatar generation process delivers realistic body shapes with the required precision in virtual body measurements and valid geometry for each pose and movement. The range of motion mirrors reality. In addition, the new process allows individual and variable adjustments. In combination with realistic fabric drape, valid fit assessment will be possible. However, one big limitation remains. So far, there are no avatars with soft tissue. Therefore, underwear, swimwear, bras, compression garments, waistbands, etc. cannot be investigated. As long as the avatar surface is rigid, the compression effect of those products cannot be simulated.

To help companies overcome possible hurdles, the accuracy of the 3D garment simulation software and the users' understanding of the technology must improve. Taking all opportunities into account, 3D simulation can only save time and money if it is combined with traditional pattern making know-how and 3D system knowledge.

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