Analysis of the Accuracy of the Moving Avatars in Style3D Using 4D Scanning

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Abstract

3D and 4D scanning technologies have revolutionized digital representation forms, particularly in the clothing industry. While traditional 3D scanning already provides detailed static models, 4D scanning extends these capabilities with the dimension of time, capturing dynamic movements and changes.

This study examines the precision and effectiveness of moving avatars created using advanced 4D scanning technology compared to the avatars and movements available to users in the Style3D simulation software. The primary objective is to evaluate how accurately these standard avatars depict real-world movements. By utilizing 4D scanning, which captures three-dimensional spatial data over time, we gain a dynamic perspective on human motion and offer unprecedented detail.

The research focuses on the comparative analysis of three key poses extracted from avatars in Style3D and a 4D scan. This involves examining changes in the mesh within these poses, assessing variations in measurements, and conducting a visual analysis of the avatars' meshes to accurately depict body shape. The study aims to highlight differences and propose methods to enhance the realism and application of avatars, particularly in the fashion industry.

Keywords: 3D Scan, Avatar, 4D Scan, Simulation

1. Introduction

Digitalization, AI, and automation are just some words currently finding their way into the clothing industry, which is also undergoing a digital transformation [1]. In some companies, digital prototypes, changes to pattern pieces, and entire outfits in just a few minutes at the click of a mouse are already standard procedures.

In order to develop digital products, the simulation usually requires a human model, the avatar [2].

3D and 4D scanning technologies, in particular, offer new possibilities for creating digital representations. While 3D scans provide detailed static models, 4D scanning extends these capabilities by adding the dimension of time and capturing dynamic movements and changes [3].

These technologies make it possible to create digital avatars for virtual fitting and design processes. This paper examines the accuracy and effectiveness of moving avatars created with advanced 4D scanning technology compared to the avatars and movements in Style3D simulation software.

The apparel industry faces the challenge of designing garments that are not only aesthetically pleasing but also functional and comfortable. Digital avatars can fulfill these requirements by allowing designers and product developers to create and test virtual prototypes before producing physical samples.

This saves time and costs. Additionally, it reduces material consumption to enable a more sustainable product development process. Furthermore, Browzwear shows, with the integration of Meshcapade in V-Sticher, the importance of dimensionally accurate and animate avatars in the simulation of clothing [4], [5].

2. Motivation

The apparel industry greatly benefits from accurate digital models that can be used for both design processes and virtual fittings. However, traditional 3D scans are not able to represent the complexity of human movement. This is where 4D scanning technology comes in, offering a dynamic perspective on human movement [3]. This technology makes it possible to capture movements in real-time and thus create more realistic avatars.

The motivation for this study lies in the need to improve the accuracy and realism of avatars used in the apparel industry. Using 4D scans could help reduce the discrepancy between digital models and real movements. This is particularly important for the development of garments that have to adapt to the body and follow its movements, as well as for functional clothing, such as protective clothing with integrated protectors, e.g., cycling clothing [6].

3. Methodology

Due to the limited scope of the article, only three poses were examined in more detail. However, the advantage of the 4D scan is that we can take a closer look at each frame and thus show the individual changes of the avatars in each movement sequence.

The three movement frames are:

- the A-Pose which is also used as reference Avatar
- the sports pose 02, which represents jumping jacks
- the sports pose 03, in which the avatar performs squats.

These movements were used in Style 3D and recreated in the 4D Scan by the author. The reason for these poses is, on the one hand, to depict a standard fitting with fitting pose 10. The other two poses are intended to represent sports movements, as tight-fitting clothing is often used during sporting activities.

3.1. 4D-Scan-Technology

The 4D Scan adds a temporal dimension to the 3D Scan [7]. This technology takes a series of 3D scans over a defined period of time and creates a dynamic model that depicts both movements and changes. This makes it possible to analyze motion sequences in detail and translate them into digital avatars. The images in this article were taken using the MOVE 4D Scan in the ITM laboratory at TU Dresden.

Twelve scan modules are available, each capable of capturing movement [8, p. 2]. The scanner enables data acquisition of up to 180 fps and a spatial resolution of up to 1 mm [9, p. 5]. Movement within 2 x 2 x 3 metres can be recorded with 12 scan modules [10].

The process of a 4D scan involves similar steps to the 3D Scan but with additional requirements:

1. **preparation:** The object or person to be scanned is positioned in the center of the 12 modules to enable complete capture. In addition, movement sequences must be planned and coordinated. The first step is to scan the person in an A and a T pose.
2. **scanning:** The scanner captures the surface of the object or person in a series of consecutive scans performed over a defined period of time.
3. **data processing:** The captured data is converted into a dynamic 4D model that depicts the shape, surface, and movements of the object or person in detail in digital space.

After scanning, the data is further processed by the IBV software and is available as OBJ or FBX, among others.

The mesh from the 4D scanner is noise- and artifact-free, which has significantly simplified the data processing for this paper.

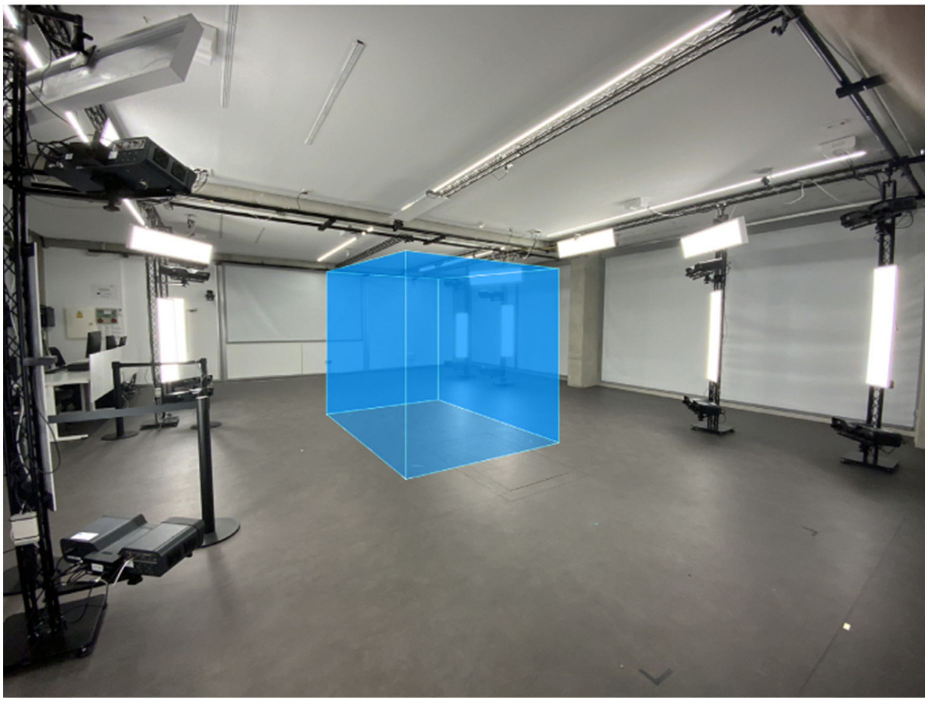

Fig.1 Capturingroom MOVE 4D-Scan [11, p. 5].

3.2. Software

3.2.1. Style 3D

Style 3D is a 3D simulation software mainly used in the clothing industry to simulate digital prototypes. The software offers the possibility of sewing, draping, visualizing, and rendering photorealistic image data within the software [12].

The functions of Style3D include:

avatar creation:

In Style 3D, the user has a library of different avatars. Additional avatars, poses, and movements can be downloaded into the Style 3D online marketplace simulation system.
The avatar's dimensions can be modified using the 'Edit avatar' function in the properties editor.
In addition, users can import avatars based on 3D/4D scans into the system.
For this paper, the avatar 'EU_Male.savt' was customized to the dimensions of the scanned person.
It became clear that although the measurements can be entered, modifying the avatar in Style 3D does not capture the correct anatomical body shape of the subject.

clothing design:

Style 3D allows the user to create and modify digital garments, which can be easily customized to fit the avatar. Through the integration in assyst.cad, users can create and modify patterns in 2D pattern software. The software offers all standard tools for digital garment creation, modification, sewing, simulation, rendering, and so on [13].

motion simulation:

As listed above, it is possible to download different animations for the individual avatars from a library. In addition, so-called Alembic files can be imported. This means that the data recorded in the MOVE 4D scan can also be used in the software (for motion the Data has to be converted into Alambic).

3.2.2. Blender

Blender is free open-source 3D software. It can cover all the requirements of the 3D world, such as modeling, rigging, animation, rendering, simulation, and more [14]. lender is not only a simulation software but is also used to analyze data sets [15, p. 1].
Blender was used to visualize the results from Rhino (capture 3.2.3.) and for the visual analysis of the Avatars.

3.2.3. Rhino /Grashopper

Rhino is a 3D modeling software for various industries and sectors. Rhino enables the analysis and simulation of complex designs in the digital world. In addition to simulation, visualization and animation are possible in Rhino [16]. Grasshopper is an algorithm editor integrated into Rhino, enabling users to create algorithms for mold generation. The advantage is that no specific programming knowledge is required [17].

Rhino, paired with its algorithmic extension Grasshopper, was utilized to perform advanced mesh analysis and evaluate the deformation behavior of a reference avatar subjected to various poses. The custom Grasshopper script developed for this study allowed for a detailed comparison between the reference avatar's key body measurements and those taken from the avatars in Sports Pose 02 and Sports Pose 03. The steps of the analysis are as follows:

1. Extraction of Reference Avatar Measurements: Using the reference avatar, the primary body measurements were obtained in accordance with ISO 7250-1:2017 standards. Specifically, circumferences for the chest, waist, hip, middle leg, and upper arm were extracted by generating polycurves along these regions. To ensure precision, each polycurve was subdivided into 1 mm segments. The barycentric coordinates of each point along the polycurve were calculated to capture the spatial relationships between the mesh vertices.
2. Reconstruction of polycurves in Posed Avatars: Based on the barycentric coordinates of the reference avatar, corresponding polycurves were recreated on the meshes for Sports Pose 02 (jumping jacks) and Sports Pose 03 (squats). As the meshes in both poses maintained an isomorphic structure with the reference mesh, this allowed for a direct comparison of how these measurements adjusted between the static reference pose and the dynamic sports poses. This process was essential to understanding how body dimensions behave during movement.

3. Edge Length Variation Analysis: To quantify mesh deformations caused by the different poses, the average edge length per vertex was calculated and compared between the reference mesh and the posed meshes. This analysis revealed localized areas of shrinkage and elongation, allowing for a deeper insight into how the mesh distorts during specific movements. The results were visualized as a color-coded gradient: vertices that experienced shrinkage were highlighted in blue (0.5), while those showing elongation were marked in green (1.5). This gradient visualization made it possible to easily identify areas of significant deformation, particularly around the joints and limbs, where articulation is highest.

4. Analysis

The following chapter shows the analysis of the two avatars in the reference pose (see Fig. 2) and the sports poses.
The measurements are also analyzed.

Fig. 2: Style 3D Avatar modified and 4D-Scan.

The avatar of Style 3D was created with the editing tool for avatars in Style 3D in which the corresponding dimensions were entered.

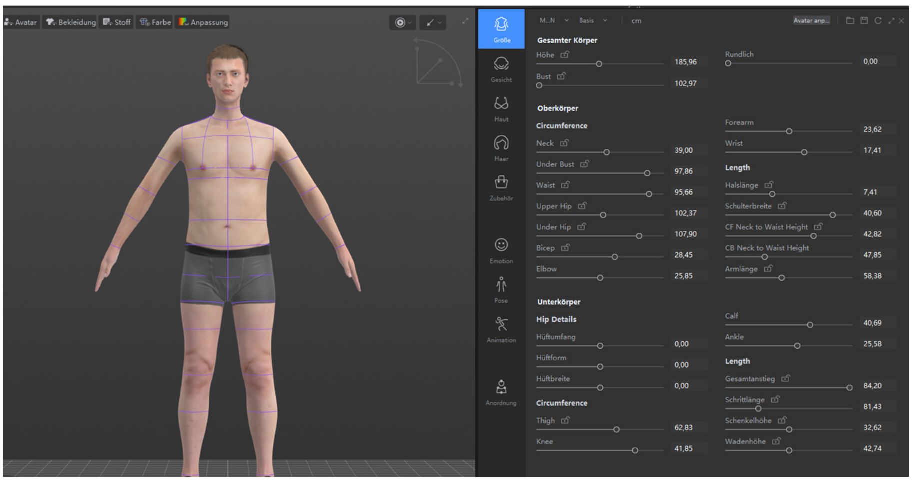

Fig. 3: measurements in Style 3D.

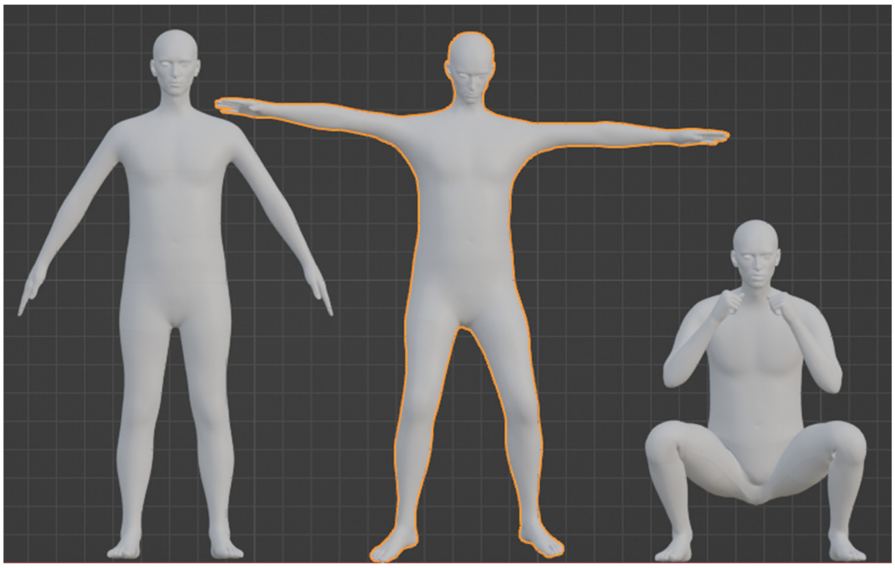

Fig. 4: Key-Poses Style 3D.

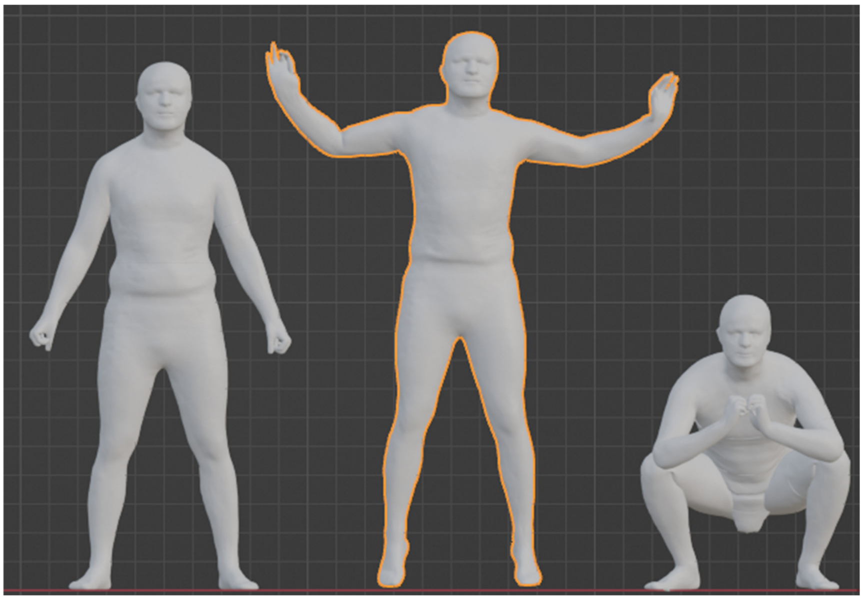

Fig. 5: Key-Poses Move 4D Scan.

The reference pose is shown on the right for both the Style 3D avatar and the MOVE 4D avatar. The Jumping Jack pose is shown in the center. The pose of the squard is shown on the left.

4.1. visual analysis

Looking at Fig 2, it is clear that the avatars show different proportions in the distribution of fat tissue. The avatar from Style 3D (left) shows a homogeneous surface, whereas the avatar from Move 4D has a heterogeneous surface between the hips and chest.

The humanized representation of the facial features and details, such as the eyes and ears, is significantly better in the Style 3D avatar and would require post-processing of the MOVE 4D avatars.

The two poses also provide this visualization (see Fig. 4 and Fig. 5). Here, too, the distribution of the skin is different in the MOVE 4D avatar compared to the Style 3D avatar, which shows a very heterogeneous surface in the upper body.

The Style 3D avatar provides an even distribution of proportions but does not represent an image of reality. Proportions are decisive for the processing of clothing, especially in the made-to-measure sector. The distribution of skin/fat tissue can also be decisive for fit development in functional clothing in which protectors are processed.

4.2. Comparison of the measurements

The following shows the measurements of the avatars in the different poses. The chest, waist, hip, arm, and leg circumference were measured in rhino for analysis.

Table 1: Body Measurements of the Avatars

	Body Measurement	Referenzpose (cm)	Jumping Jack(cm)	Squad-Pose
MOVE 4D	High	183,81	not measured	not measured
	Chest circumference	106,691	107,393	107,654
	Waist circumference	94,909	100,985	95,434
	Hip circumference	111,951	110,57	112,325
	Upper arm circumference	55,316	57,013	56,685
	Mid-thigh circumference	35,269	33,124	36,59
Style 3D	High	186,661	not measured	not measured
	Chest circumference	103,895	106,907	104,177
	Waist circumference	95,697	95,694	95,493
	Hip circumference	106,594	106,059	108,116
	Upper arm circumference	48,593	48,586	47,55
	Mid-thigh circumference	27,594	27,857	27,407

The dimensions entered in Style 3D do not match those of the measured avatar. For example, Style 3D can use a subdivision to smooth the mesh, slightly modifying the final dimensions during export.
The deviating body height of the Move 4D avatar results from the different leg positions of the reference pose and the measurement of the real dimensions.

Having a closer look at the chest circumference, the Move 4D avatar is consistently larger than the Style 3D avatar. The size of the scan avatar is consistently larger than that of the Style 3D avatar. However, the chest circumference of the Move 4D avatar only changes by a maximum of 1 cm in both poses. Meanwhile, the Style 3D avatar changes by up to 3 cm. The significant change in chest circumference may be due to a lack of muscle and tissue deformation simulation.

The waist circumference remains constant throughout the Style 3D Avatar, whereas the Move 4D Avatar shows an exorbitant change from the A-Pose to the Key Pose Jumping Jack. This is another point that shows that the MOVE 4D avatar may better capture the dynamic change in body shape during movement.

The leg circumference makes it clear, especially in the squad pose, that the Style 3D avatar does not map the muscle contraction in the poses, as the thigh muscles, for example, are contracted in squads, resulting in a dimensional change [18]. The quadriceps femoris, in particular, is heavily strained here [19]. Jumping jacks, for example, also strain the thigh muscles, leading to a change in size [20].

With the Style 3D avatar, the dimensions of the reference avatar and the avatar in the Jumping Jack position do not change. However, the thigh circumference of the reference avatar and the avatar in the squad position does change.

Table 1 also shows a change in the arm circumference of the MOVE 4D avatar, while no change is visible in the Style 3D avatar, suggesting a less dynamic mesh change during the movement of the Style 3D avatar.

4.3. Advanced Mesh Analysis

The detailed mesh analysis of the avatars is shown below. The two poses are considered individually. The avatar in the key pose is shown in gray, the heatmap with the stretching (green) and compression (blue) of the mesh is shown on the reference avatar.

4.3.1. Sport Pose 2 – Jumping Jacks

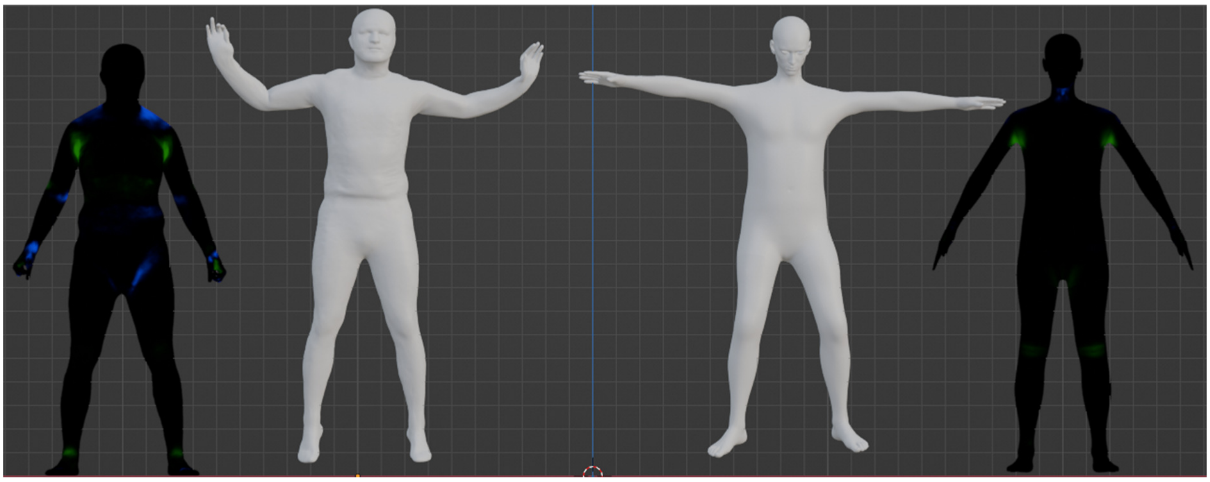

Fig. 6: Mesh deformation Jumping Jack front.

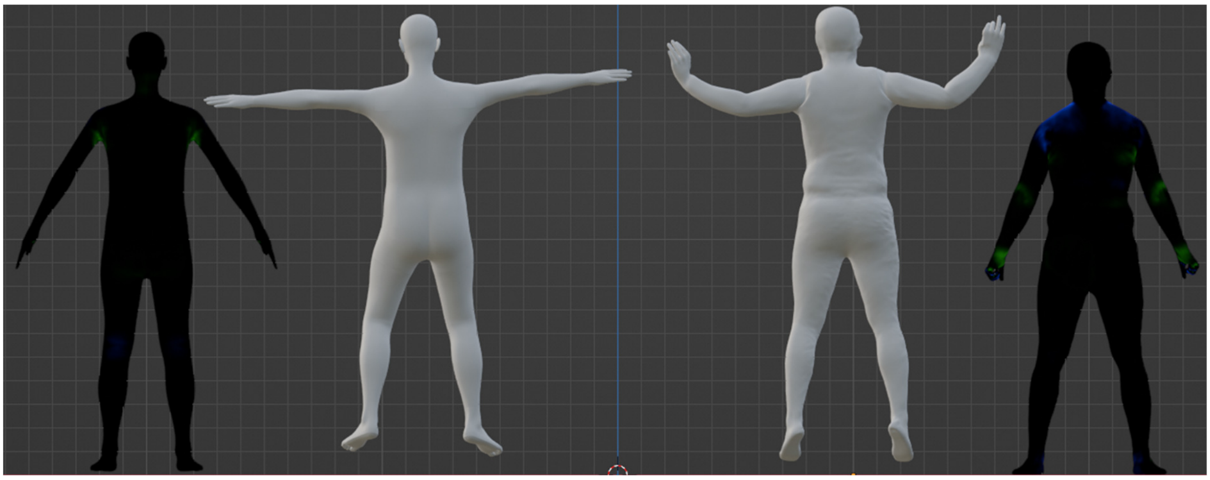

Fig. 7: Mesh deformation Jumping Jack back.

When comparing the Jumping Jack pose, differences in the mesh deformation of the two avatars become clear.

In the shoulder area of the MOVE 4D avatar, an apparent shrinkage of the mesh can be seen, which is also evident on visual inspection. There is a gap in the area of the shoulder blade and the arm, which already indicates a compression of the surface, which was made clear by the mesh analysis. The Style 3D Avatar shows only a slight compression here. This could be because the Style 3D Avatar does not depict the body deformation as precisely as the MOVE 4D Scan.

In the knee area, the Style 3D Avatar shows a slight elongation at the front and a slight compression at the back due to the bent knees during movement. Similar behavior is observed in the ankles of the Move 4D avatar, as the feet are bent forward. Both avatars show a clear stretch in the armpit area, which is due to the dynamic arm movement during the pose.
The MOVE 4D avatar shows a slight compression on the inside of the left thigh, while the Style 3D avatar shows an elongation in comparison.

In the elbow and hand area of the MOVE 4D Avatar, the mesh is compressed, which is not noticeable in the Style 3D Avatar. This is due to the different execution of the movement, as the Style 3D Avatar performs the movement with outstretched arms, which results in less compression in the area of the elbows and hands.

4.3.2. Sport Pose 03 – Squads

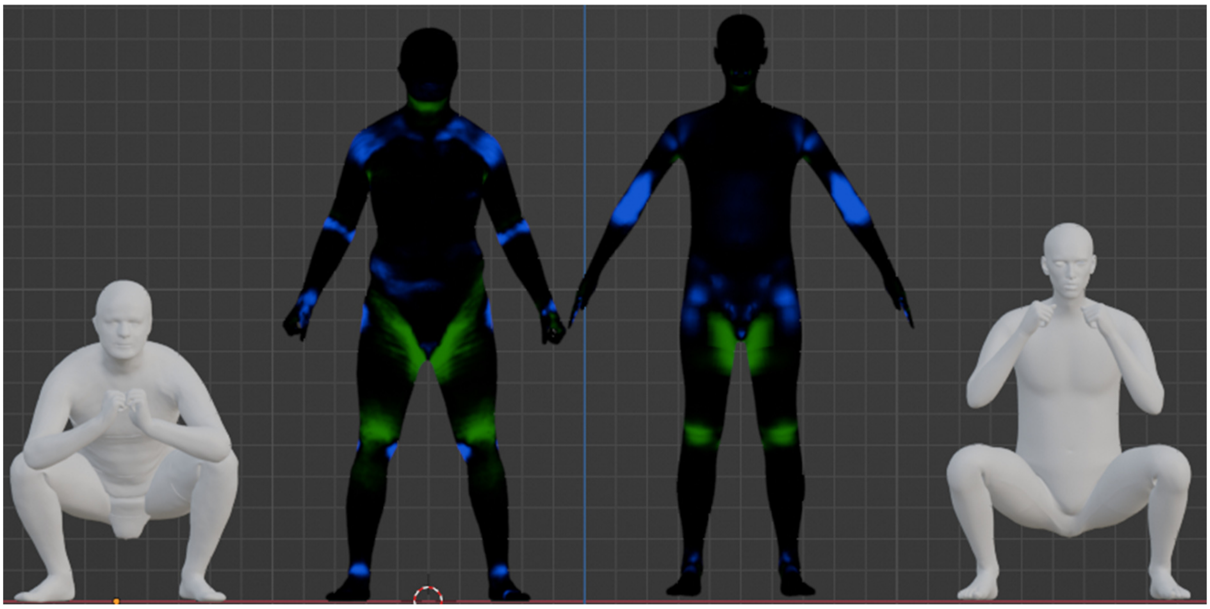

Fig. 8: Mesh deformation Squats front.

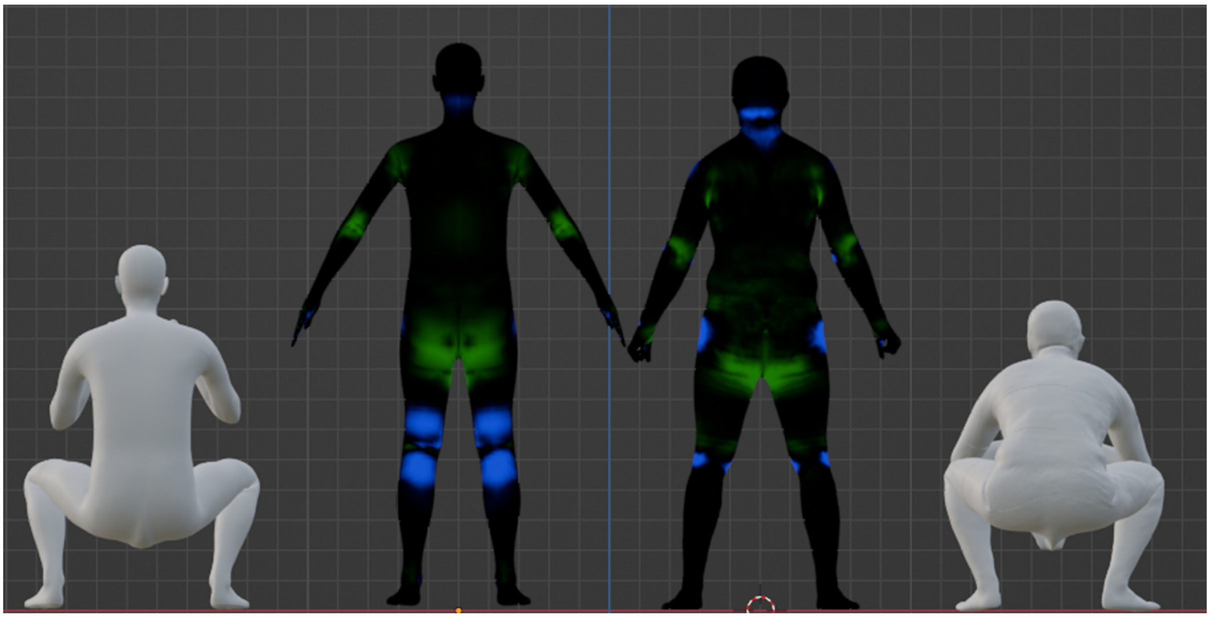

Fig. 9: Mesh deformation Squats back.

When analyzing the deformation of the avatars, it became clear that there are slight differences and similarities in the stretching and compression behavior of the body surfaces.

The MOVE 4D avatar shows a precise compression in the shoulder area, which indicates compression of the mesh structure during movement. There is also a recognizable compression in the buttocks and hips, especially where a fold forms during movement in reality.

In parallel to the MOVE 4D avatar, we see a strong compression in the area of the inner upper and lower arms, especially in the area of the elbow. This deformation can be attributed to the significantly more bent arms of the Style 3D avatar, which points to the differences in the movement modeling.

When analyzing the stretching areas, similar stretching patterns can be seen in both avatars' knee area and buttocks. However, these strains are more pronounced in the 4D Scan, which indicates a more realistic representation of the body movement. On the other hand, the compression in the ankle area is almost identical in both avatars, indicating comparable deformation and movement in this region.

5. Conclusion

The analysis showed that the body proportions can be better captured by the MOVE 4D scan in the individual poses compared to the Style 3D avatar, which only offers minor modification options for the body proportions.

The analysis of the dimensions makes it clear that the Style 3D avatar can be used in the software itself but that there is a slight change in the dimensions when exporting. The measurements in the key poses show that they change more dynamically with MOVE 4D compared to the Style 3D Avatar. This shows that the 4D scan depicts the real movement-related changes to the body more precisely than the Style 3D avatar does. Compared to the dimensions, the latter reacts significantly less to movement.

The mesh analysis makes it clear that the MOVE 4D avatar sometimes captures more subtle changes and movements compared to the Style 3D avatar. The characteristics of compression and extension in both poses make it clear that the MOVE 4D avatar depicts the reality of movement in the mesh more clearly.

Both avatars show similar deformation patterns in the individual poses. The clarity of the change in the mesh and the partially unchanged dimensions of the Style 3D avatar allow the conclusion that the MOVE 4D avatar better depicts the reality of human body changes during sports movements.

The Style3D Avatar in Motion allows users to simulate and digitally adapt clothing in static poses and dynamic movement sequences. This opens up new possibilities and perspectives for digital clothing development. However, a generic avatar is not enough to ensure exact comparability with the real world. In order to achieve a realistic representation, a human model that reflects the exact proportions of the real-life model is required.

This is where the strengths of 4D scanning lie, as it makes it possible to transfer the actual movements of a real person into the digital world. This detailed depiction of body shape and movement achieves a much higher level of comparability between the real and digital worlds than would be possible with Style3D standardized avatar, which is individualized through its own measurements. The 4D scan creates the basis for analyzing the fit of clothing in motion more realistically than in Style3D.

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