

Why Does the Apparel Use Case Need a Different Approach to the Rig/Weight Systems?

Katy SCHILDMEYER*¹, Carol MCDONALD², Amelia SCHILDMEYER DC³

¹ Design Cycle Solutions, New York, NY, USA;

² Gneiss Concept, Washougal, WA, USA;

³ Somaticpdx, Portland OR, USA

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Abstract

Current rig systems have been developed for use in games, film, and virtual environments. Based on 2D images. The utilization of these rig systems impacts fashion waste. Examined rig systems are focused on art and speed related to imaginary environments. These systems unfortunately do not help the design use cases for apparel. Current rig systems are useful for understanding poses for humanoids. However, overlooking natural posture, shape, mass, movement, and curvature of humanoid(s) cause mathematical fidelity to suffer, and impacts the quality of digital garment displays, and therefore the fit accuracy of the modeled coveroids (garments or footwear). This is essential for humanoids based on body data of an actual humans obtained by 3D body scanning or data input. Utilizing the PARCS descriptors for posture (placement, alignment, rotation, curvature and symmetry), to accurately describe the rig that is obtained for humanoids, allows for a better understanding of differences between the modeled rig and actual skeletal requirements. In the rig/weight system presented, rigs can be adjusted for gender and/or body mass differences, as this is essential for intimate apparel design.

After creating the rig for the humanoid, weighting for the vertices follows. Weighting is the technique of designing how much influence each joint has on each mesh vertex. This binds the mesh skin to the joints (rig) and allows for mesh morphing alignment with the joints during movement. If the weighting is restricted to limit the number of vertices to each joint, the subtlety of movement cannot be fully described. In the weighting system presented, weighting can be graded for body mass or body movement.

Multi Person models use an average to configure and calculate folding variables and form a skin (mesh). However, the modeling of the fabric for coveroids needs to interact properly with the humanoid and coveroid. It is critical to be able to attach rig systems from the humanoid to the coveroid for proper movement of the coveroid, in addition to setting up the collision values that relate to the shape, mass, movement and curvature of the humanoid.

Apparel has a need for a new system that works as an apparel engineering tool versus a simulation tool for designers to reduce waste and deliver mathematically sound products. Appropriate programming for deep learning and AI is not possible without better data.

Keywords: 3D body scanning, rig systems, weighting, posture descriptors

Introduction

Apparel design has had a long-standing issue with the quality of formation, stature and stance of 3D humanoids. This has been overlooked and misunderstood because of various geometric, algebraic, and trigonometry-based physics that describe clothing's relationship to the body. Commonly, an anthropomorphic solution overlooks the unique needs of apparel design use case as they are general 3D humanoid providers [3] while the apparel use case is arguing that the current methods of measuring locations or deriving averages for morphotypes lack along with the actual presentation of posture.

A pattern maker relies on the natural state and stature of a person for accurate pattern making, while anthropomorphist deem a straight stance that comes from the rig underpinnings to be an appropriate tool for shifting and adjusting a humanoid figure [4]. The usual 4 to 6 joints as a spinal method, limits shaping and movement related to spinal conditions that require custom clothing, and shapes associated with pregnancy, aging, and bone disorders. In many cases, apparel applications, the measurement tolerance can be as small as 3mm depending on specifications and product relationships to the age of the humanoid and sizing intervals that are planned.

Examples such as bra design require a 3mm difference for bra designs specifications related to fit, preemie-to-newborn onesies due to size of garment have tighter tolerances or smaller measurements e.g., wrist circumferences have tighter tolerances than larger body circumferences or length measurements. Design Cycle Solutions [16] and Gneiss Concept [15] developed a rig system that changes the formations of the figures posture to meet the needs of issues like lordosis, kyphosis, scoliosis, and other spinal conditions. Somatic PDX [19] informed the location of rigging joints related to spinal conditions.

The secondary reason for having more options available in the accuracy of a humanoid with relationship to apparel is associated with global waste systems. Apparel is the seventh largest industry with the second largest waste impact globally. The rapid adoption of 3D in a post covid supply chain saw an escalated return rate based on fit grow from 42% of returns tied to fit to a 75% fit related return ratio according to retail federation 2024 results [17]. A proposed universal fit avatar registry should be assembled to track and assign fit ID to every digital and static humanoid used for apparel development within brands to tie the humanoid to the product. This method tracks success of sell-through for products tied to a digital humanoid utilized for the final product and allows brands a free forum to find what works locally, nationally, and globally.

1. Understanding the Design Process

Humanoid Design that is related to Apparel design is not just only reliant on a set of measurements. PARCS and anthropomorphic data are crucial to fit. Often people consider all humanoids can be made universal. However, our own biology is different based on human behavioral data. Shape of body in relation to PARCS [2] is crucial to setting the foundation for fit application lanes. Reviewing the evolution of a pattern is necessary to developing shapes related to the fit needs of the demographic market. A sloper [20] or toile is a 2D representation of the body. The sloper is not an "onion-skin" but incorporates shaping techniques such as darting to form the shape of the body. The sloper is defined as set of mathematical curves. These have extraordinarily little ease, whereas pattern blocks are basics with ease for textiles used.

The sloper image below is the blueprint of this participant's body and body scan. The fit is extracted via the sloper and transposed into every style that comes from this item, Figure 1. Slopers inform the basic pattern blocks that can turn into more complex styles. Also known as "mother pattern".

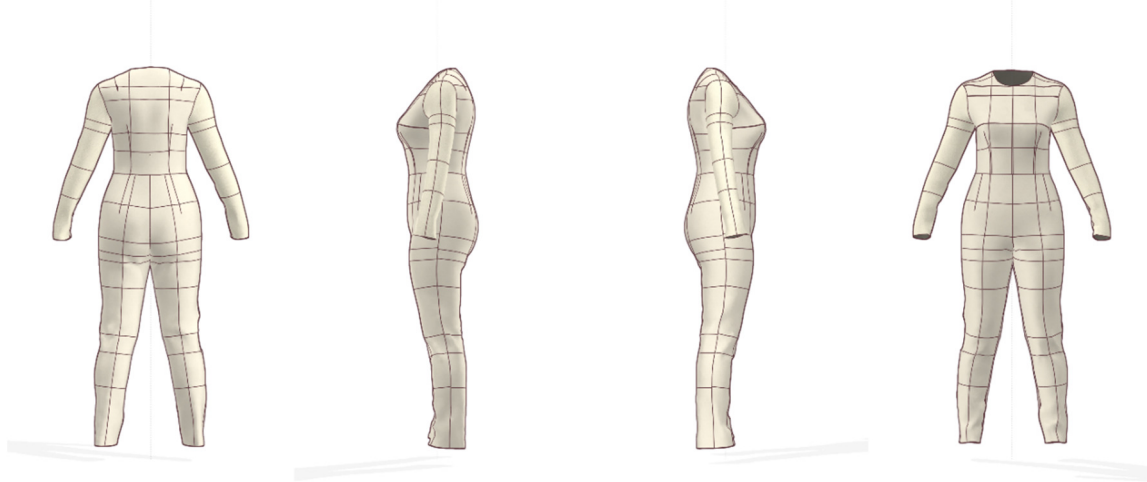


Fig.1. Sloper Points of Measure

Measuring sloper points of measure do not directly call out stature and stance, each point of measure (POM) is generating the 3D math of stature and stance. Height is a crucial value for this process. Poses are also crucial. T-pose and a wide A-pose are not natural positions and may only inform the pattern. The natural stance I-pose and a pose that relates to the product categories may be better to be used to get the information required. Knowing other poses are needed may change how many scanned positions are needed by each brand or use case. [2, 4,5,10,12]

2. Example of what happens to a sloper when placed on different 3D bodies with the same measurements but with different shaping.

The participant was scanned using Apotheosis 160 camera photogrammetry scan. For this study, the mesh generated from this scan was considered the “ground truth”. The impact of using different tools on the fidelity of the resultant mesh and rig systems were then analyzed. The validity of fit amongst different meshes and rigs can be compared. The scanned obj was imported into various apparel CAD and therefore the standard rig systems provided by those CAD were used. The rig systems consist of a predetermined number of joints that inform the way that a humanoid moves to mimic the way a body moves with flesh and muscle. It also informs longitudinal growth behaviors. The scanned mesh was also imported into three common autorig tools to understand the impact of those rigs as explained in Section 3.

A few methods were used to review fit issues and found the limitations of the current rig systems played a role in this process.

Table 1: Comparison of Spine and neck joints

Provider	Humanoids Used in Sloper tests	Pass or fail	Spine Joints	neck Joints
A	Apotheosis Rig from 160 camera Photogrammetry Scan	Pass	10	4
B	3D program - Avatar using the morphing controls to match	fail	4	2
C	Dress form supplier ASTM with near match	fail	0	0
D	D3D program - Avatar using morphing controls	fail	6	2
E	E 3D program supplied Morphing Avatar tool	fail	4	2

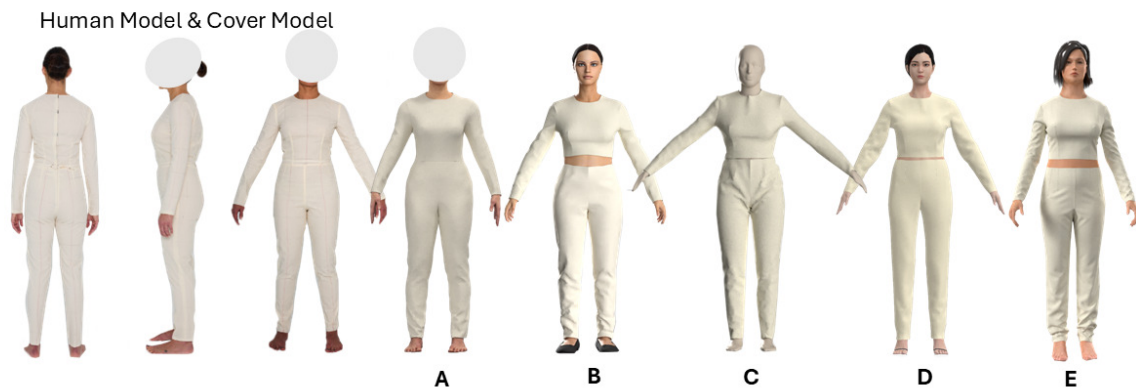


Fig. 1. Sloper on forms that have similar measurements with same garment sloper

Table 1 compares the number of joints between the various suppliers while Figure 2 shows the impact of the differences of the slopers. An ideal sloper should be smooth to the body as shown in the first three humanoids and is considered the “ground truth”. It is rigged with the Apotheosis System for Apparel. There is some slight bunching of fabric in the legs in Figure 2, fourth humanoid from the left, labeled “A” but within expected ranges. While B-E are various widely used tools. Aspects of posture or pelvic tilt as well as neck and shoulder posture are key issues of fit and are largely related to the limited nature of the joints within the rig systems. Differences are shown by the gap between the upper and lower body, excessive bunching of the material in the legs, and folds of material in the abdomen area.

Apotheosis [16] was made to fix issues and limitations related to rig systems associated with speed for gaming. Not one of the above models are incredibly useful for the full range of evaluating a form for reality because of the limited structures. This is related to the stature and stance as well as continued formation of the human form in various positions. In addition, Apotheosis was awarded the 2023 3DRC Grand Challenge prize [18].

Clothing design tools should be able to support a multitude of shapes, postures, and ages [6,9,11]. The made -to - measure market is a key market for avatars and body scans. Having a tool that can be used for shaping is crucial. The image in Figure 3 shows the apotheosis patent pending system and the standard system provided by Provider B in D3D along with provided X-ray. Due to a lack of spinal joints, formations of curve are hard to achieve, which then change the assumed specifications in measuring and positioning of the body and therefore the balance and design of the end-product. Digital humanoid products have shown to have poor outcomes in relation to these variants in apparel and create wasted time, money and physical goods.

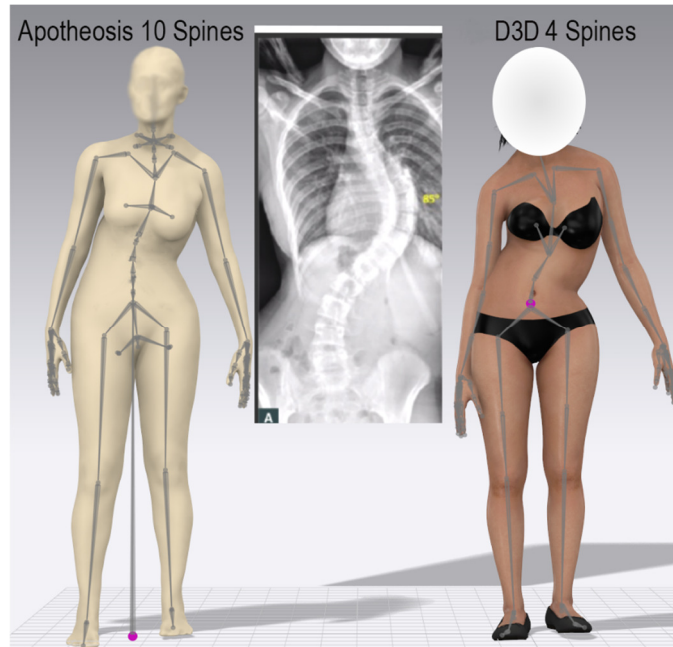


Fig. 2. Spinal Scoliosis and ability to achieve form related to stature and stance.

3. Measuring the Impact of Auto rigging tools on accurate body scanning tools.

Apparel Design is a form of engineering, and every measurement informs another measurement. Joints also inform measurements, posture, and shape [7]. The body scan was analyzed by importing the mesh into three different autorig tools. The outputs of these tools were then analyzed in Rhino software [14]. These tools and measurements in relation to distinct positions were tracked against our specs from the “ground truth” model. The floor was used as the null and measurements are placed in same height from floor to placement of circumference. The four different OBJs are shown in Figure 4 for visual comparison. The systems changed key aspects related to apparel design as compared in Table 2. The “Not meeting specs 5+” means that more than 5 POMs were not in line with the specification of the model.

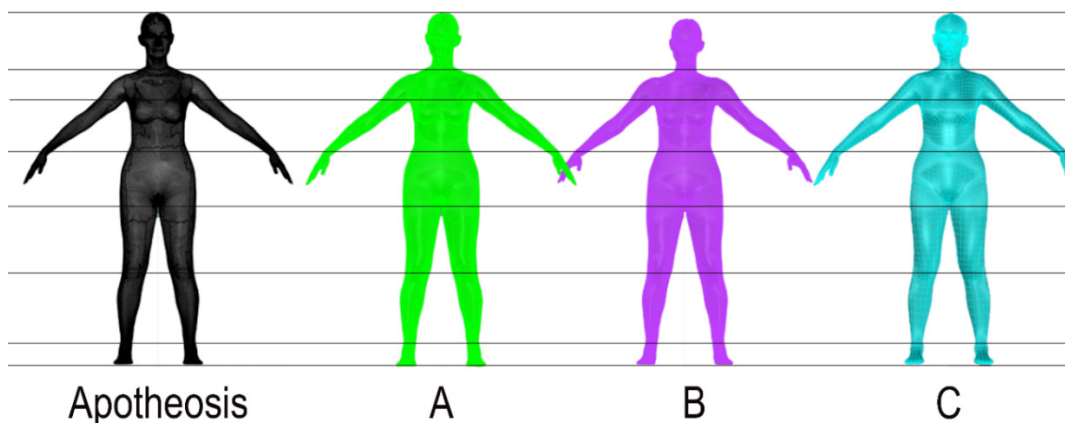


Fig. 3. Images of the body scan placed into three auto rigging systems.

Table 2: The key aspects related to apparel design.

Rig Systems	Basics		Changes			
	Vertice count	Face count	Mesh	posture	limbs	Not meeting specs 5+
Apotheosis	161,516	161,621				
A	161,516	161,621		x		
B	161,516	161,621		x		x
C	10,475	10,578	x	x	x	x

3.1. Tracking posture and Mesh changes

The rigs and the impact on the mesh were compared between the providers. The Apotheosis System [16] for Apparel was still considered the “ground truth”.

The rig systems C replaced the mesh of the neck and head. The neck, shoulder and head inform shirts, dresses, jackets, and any garment that hangs from the shoulders. When removal of these regions occurs, it voids the form from the use case of fitting for apparel. This action impacts balance from front-to-back, shoulder, armholes, and breast placements.

The rig systems B removed the natural posture of the body. Removing the natural posture impacts trouser, dress, and upper body fit of apparel. The rise of a pant or the shape of an armhole can change due to the repositioning of posture. The leg balance can also impact the rise and torque of a trouser. [1, 5, 7]

The rig systems A was the closest to the “ground truth” even with head turned slightly in a different direction. The shoulder length and rotation changed slightly.

Within Rhino [14], among the four loaded OBJs figures, the center back curve was compared within the same lower and upper height for each of the providers as shown in Figure 5. For each back center curve, 16 evaluation points were used to standardize the number of evaluation points between each curve. The horizontal and perpendicular frame planes along with the tangents of the curve were found at each evaluation point. The discontinuities of each curve can vary by curve (showing the tangent changes of the curves) and may be an artifact of Rhino modeling of the curves.

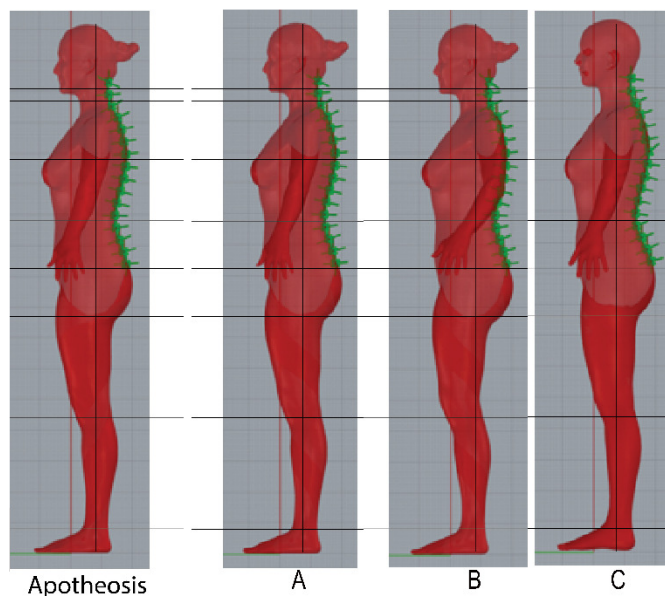


Fig. 4. The 16 evaluation points were used instead of discontinuities of each curve. as the number of discontinuities can vary by curve.

The impact of Humanoid C having changed the mesh of the body is that the mesh impacts and informs every measurement. The smaller number count of faces/vertices of the mesh count, the more rigid and vague the measurements can become in movement.

Out of the three rig systems, only one had shared tolerances of measure in the binding A-Pose. This implies that the other options are not going to deliver the intended fit solution. These solutions will work great for gaming or simulations but not for production engineering solutions. Industry goals are to reduce samples with 3D tools. As well as inform internal LLM models.

While charting over 63 Points of measure, Humanoid A in A-pose was 98% in agreement with the “ground truth” for this body shape. However, this accuracy changes in posing options. While Humanoid B and Humanoid C failed to deliver a match to the form. This was due to how a rig structure scales bones in relation to a loaded OBJ. Some key POMS are in Table 3 that would impact collars, sleeves, length of a top or dress. These show the issues a brand may see in trying to find a digital solution with rig systems.

Table 3: Center measurement comparisons

Measure	Apotheosis (ground truth)	A	B	C
Height	171.27 cm	171.27 cm	170.76 cm	171.38 cm
CF neck to waist	36.95 cm	36.98 cm	36.97 cm	35.37 cm
CB neck to waist	40.19 cm	40.19 cm	40.18 cm	38.26 cm
CB to shoulder to wrist = cervical arm	72.61 cm	72.61 cm	71.15 cm	74.38 cm

CF= Center front CB- Center back

3.2. Pose Impact in relation to the rig system and fit.

The various rig systems and joints related to majority of posture in the trunk, shoulders, and leg are shown [1]. Note the position of the shoulders and legs change positions slightly due to the joint structures as shown in Figure 6. The structure of the shoulder connection to spine impacts the shaping of the upper back curvatures which in turn may cause issues with fit.

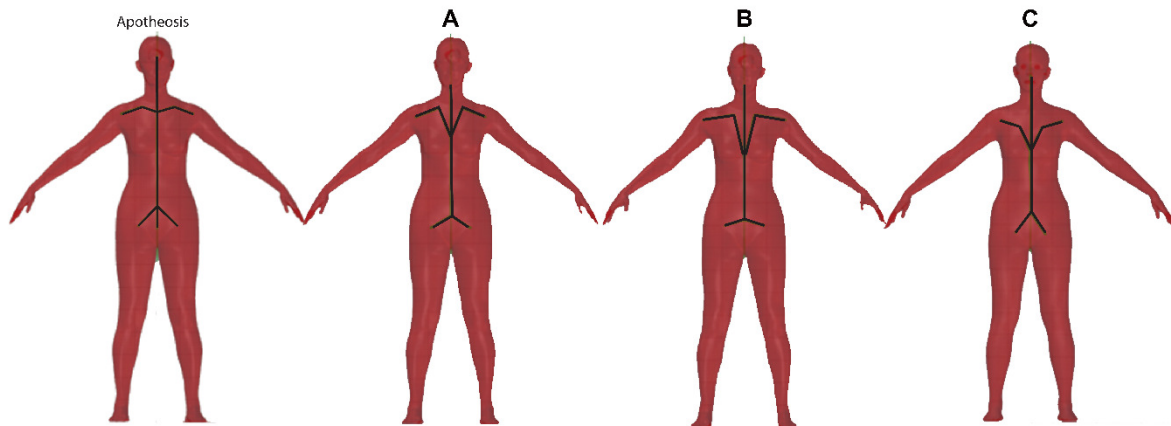


Fig. 6. Rig Structures impacting posture.

Once a rig is placed and weighed, the positions must be tested as weighting can change mass and accuracy of the overall movements. The I-pose (Lordosis) with stooped posture and sitting pose with default posture where also other postures/ poses were examined as these are common occurrences. The sitting pose is arms forward for both computer work and driving work. The sitting position had the legs lifted instead of moving the body such that the feet were in the null position. This allowed for the sitting pose and stooped posture, the heights of the center back curve was from the same lower height until the top of the neck which was not at the same height [7,9]. Utilizing 16 evaluation points allows for an easy comparison between the curves by evaluating them at the same starting point as shown in Figure 7.

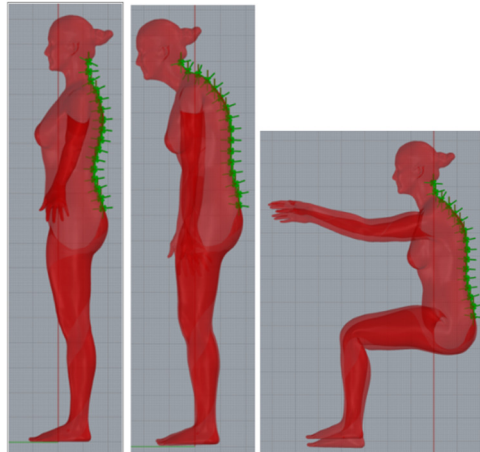


Fig. 7. A-pose, Stooped Lordosis I-pose, and sitting/ driving pose.

The measurements for key specifications for each body are listed in Table 4. According to the paper *Effects of Different Body Postures on Anthropometric Measures* published in 2016 [10]. The calculations of body changes by region could be 5%-16% at crotch girth. Understanding that the rig segments can change these girths by a full size or more impacts the waste systems of clothing. It appears to the authors that rig system providers tend to overlook how bones longitudinally grow [9,11,12], Apotheosis [16] collaborated with a chiropractor to review placement and growth of the joint systems.

Table 4: Measurement comparisons tables for stooped posture and sitting pose.

Measure	Apotheosis A-pose	Apotheosis I-pose stooped	Humanoid A I-pose stooped	Humanoid B I-pose stooped	Humanoid C I-pose stooped
Height	171.27 cm	166.71 cm	165.53 cm	164.99 cm	164.84cm
CF neck to waist	36.95 cm	35.14 cm	33.25 cm	34.99 cm	32.42 cm
CB neck to waist	40.19 cm	43.20 cm	43.45 cm	41.04 cm	41.34 cm
Cervical Arm	72.61 cm	76.85 cm	76.27 cm	74.74 cm	79.46 cm
Low hip	100.65 cm	101.17 cm	100.92 cm	100.93 cm	102.89 cm
Thigh/seat	57.53 cm	58.11 cm	57.59 cm	60.02 cm	62.78 cm

Measure	Apotheosis A-pose	Apotheosis Sitting	Humanoid A Sitting	Humanoid B Sitting	Humanoid C Sitting
Height	171.27 cm	130.03 cm	131.50 cm	134.00 cm	134.84 cm
CF neck to waist	36.95 cm	34.59 cm	35.04 cm	34.42 cm	32.42 cm
CB neck to waist	40.19 cm	42.34 cm	41.40 cm	41.67 cm	41.34 cm
Cervical arm	72.61 cm	73.63 cm	75.68 cm	76.34 cm	79.46 cm
Low hip	100.65 cm	103.15 cm	100.01 cm	103.64 cm	102.89 cm
Thigh/seat	57.53 cm	61.63 cm	56.28 cm	58.32 cm	62.78 cm
Back rise	35.47 cm	41.01 cm	48.25 cm	35.74 cm	44.35 cm

3.3. Thigh Girths

The thigh, girth and hip measurements impact how to make trousers and how the pattern shifts for the leg when sitting or moving. The image in Figure 8 shows a cross section of the base body truth in green and the red being another system. The same height location and radius change directionally.

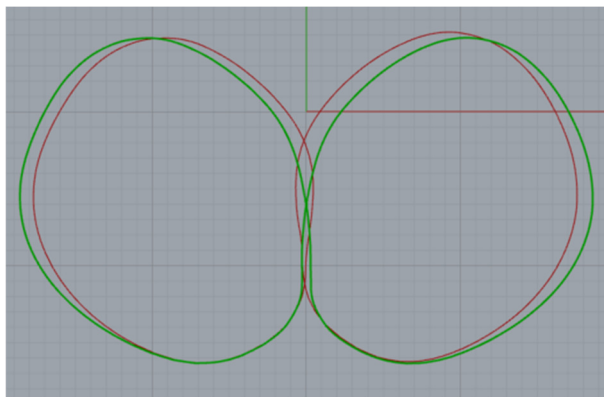


Fig. 8. Thigh shape is based on rig. Green is base body or ground truth, and red is another rig system.

4. Impacts in clothing fit analysis for 3D

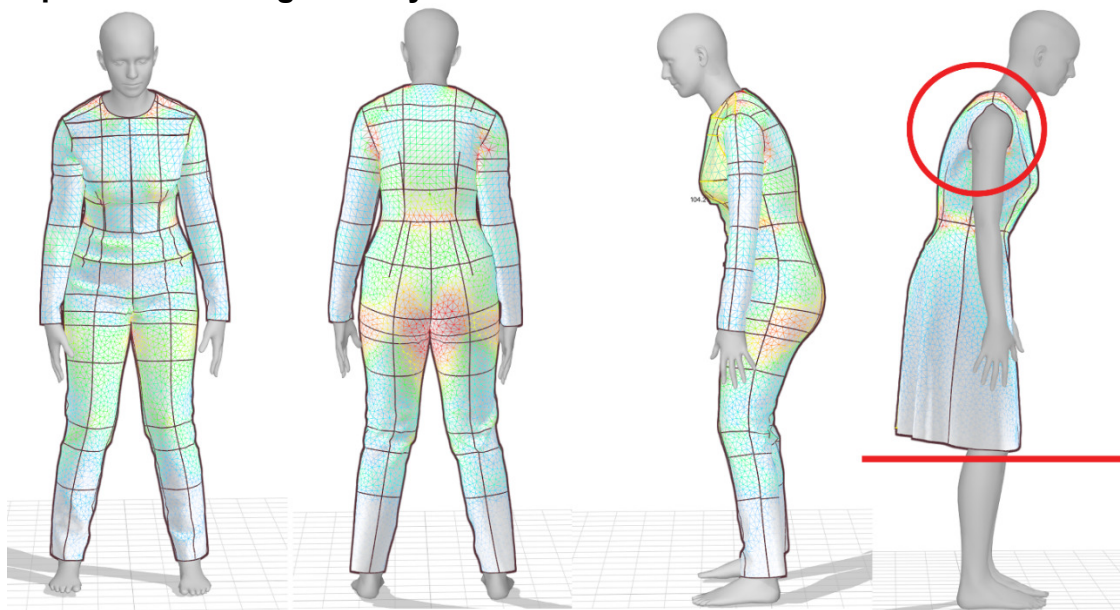


Fig. 9. The fitting of the garment would fail from the start due to changes made by the rig tools.

Figure 9 shows the “heat map” for the sloper made for this participant in a stooped posture in an I-pose on the Figure C humanoid. The blue color shows looser fit and the red show a tighter fit. The fit is already very tight through the back, as the length of the body is changing by 5 cm. This can be seen in the red at the waist and under the buttocks. However, the model still requires 2 cm of additional back length. The dress is a garment that is extrapolated from the sloper and has some serious issues in the armhole, the shoulder seam placement and collar fit in front is tight.

When a garment fits properly, it is said to be in “balance”. One of the visual clues for balance is when a dress is supposed to have a hem that is nearly parallel to the floor, that the hem is nearly parallel to the floor when standing in a natural posture. Therefore, on this dress it is unbalanced as it is angled at the knee and waist instead of being horizontal and parallel to the floor. The block dress may seem that it fits okay even with over 70% of POMS not aligned with specs of stooped posture I-pose on the ground truth. A more accurate avatar will impact on the fit and clearly show any deviations of fit in key locations on the body.

Often new pattern drafters or non-fit technicians are unaware of what to look for when defining ease and physics related to fabrics impact with poses. They will assume it will pass and send it to production. This is how apparel has become second leader of waste globally while the profit margins are in single digits.

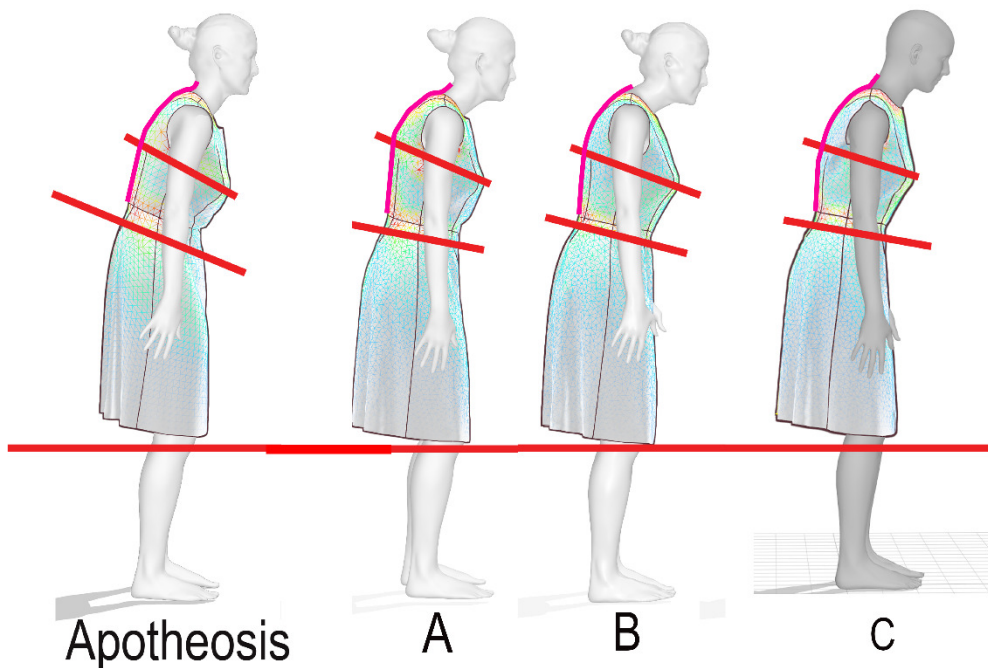


Fig. 10. shows the same dress block being fitted to all systems. The lack of capability in obtaining the posture of A,B and C impacts obtaining the same curve as Apotheosis for the center back length

Figure 10 shows the same dress block being fitted to all systems. The lack of capability in obtaining the posture of A,B and C impacts obtaining the same curve as Apotheosis for the center back length as the posture angles are also limited [2]. Since a stooped posture can extend the center back lengths by 15 cm for some, it means fit issues can not be solved that impact up to 40% of the population over the age of 50. A considerable margin of error for the population. The lower pelvic body is also limited in systems A, B and C, so the glutes and front pelvic tilt are not realistic for a posture of this nature. Apotheosis [15] figure has a flattened backside glute region. Apotheosis has created 3 centers of gravity in the system to manage the needs of pelvic rotations, tilt, and gluteal mass.

The Apotheosis dress looks like it has the worst case of fit. Why is this the case? The pattern reacts to the participant's body length of the back. Since the Apotheosis humanoid more accurately reflects the stooped posture, the differences between the garment and the humanoid will be greater. The new sloper top pattern in Figure 11 is 7cm longer than the original pattern. The front of the pattern is too long for the participant which center front (CF) neck to waist and high point shoulder (HPS) to waist. These measurements can be seen in Table 4 where the center back increases in length, and the front center decreases due to the stooped posture. After visual examination, it is apparent that a new sloper is preferred for the specs of this participant's body to gain a well-fitting garment for this type of posture.

4.1. Dress Fit vs Dress Fit.

As noted previously, a balanced pattern, for this style of dress, the hem will be parallel to the floor. To truly see the impact of different postures on a body, balanced patterns are needed for both the extreme curved back and the slightly curved, natural posture. This means that due to the initial pattern being made for a different posture, it impacted the fitting. For this reason, the pattern had to change to rebalance the garment and create a straight waist and parallel hem for this garment. The poor fit is the dress made for the starting pattern. Neck down balance issues make for a poor fitting garment.

Figure 11 shows the new dress with a sloper top used to show the new balances. The waistline is balanced with proper side seams, and the hem hangs equal to front and back. The pattern made for a non-stooped natural posture had issues in the front and back neck, breast fit, and front and back balance on the skirt. The hem also hangs longer in the front to the back.

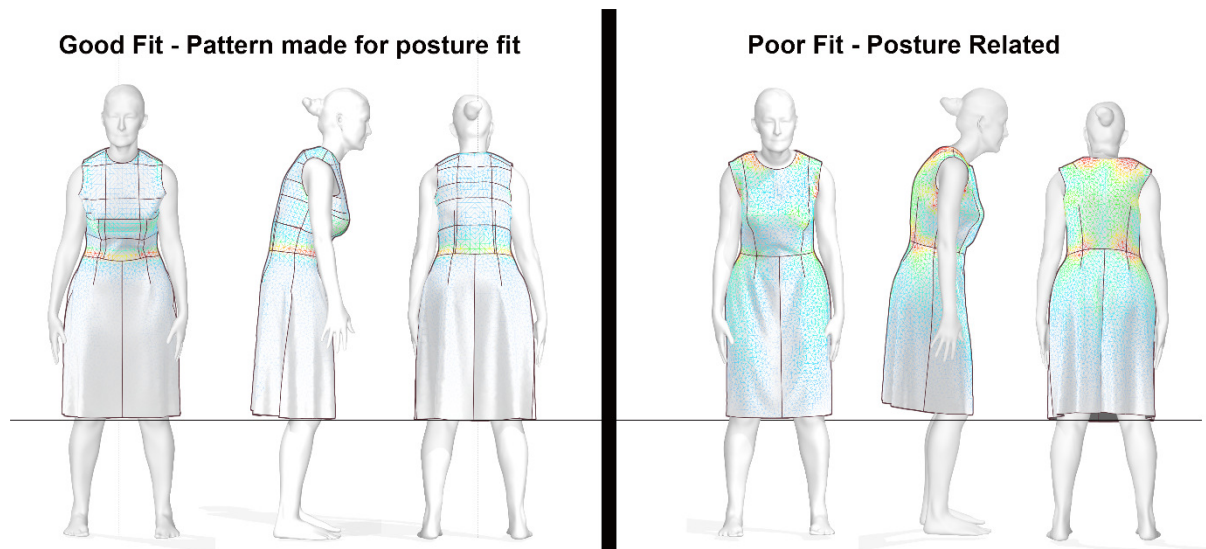


Fig. 11. New Sloper top bodice that is made for this dress. The stooped posture required a different fit to rebalance the dress.

5.The need to design tools for design use cases and not for simulations alone.

Apotheosis was created out of a need for a tool that could allow for the engineering of garments successfully while reducing the sample process. In our beta tests with 25 pattern makers, they preferred the Apotheosis system over the Provider C systems or using the CAD apparel software for rigs. The formations, and mass size changes in poses with differentials-of-mass are key components for enjoying the tool.

Pattern drafters also found the ability to extend the body into the class of people with fit issues was also helpful for any custom products they may have for fashion shows and private clients. Ultimately the goal to reduce waste and have a way forward with made-to-measure needs in the marketplace must start to a better solution related to the needs of apparel engineering. Given that younger populations are already experiencing higher rates of lordosis and hip related issues due to technological devices and less exercise, along with 40% of the population over the age of 50 experience posture curvatures that are not normative, issues are anticipated with 3D Humanoids with current options, having a great impact on the clothing waste issue.

Future research would include expansion of testing with additional body shapes to determine the boundaries of the rig and software with our patent pending graded weight protocols.

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