A 3D Anthropometric Approach for Designing a Sizing System for Tight Fitting Garments

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Abstract Current sizing charts on the surfing market have been set up with the use of surveys and optimized based on customer feedback. It might not consider the entire population outside their current customer population. Furthermore, these sizing charts are created based on one dimensional measurements and therefore do not capture the full shape of the human body. The purpose of this study is to develop a new approach in creating sizing systems of wetsuits for the surfing industry, using readily available tools. A good sizing system focusses on the balance between fit, comfort and functionality. The industry has been relying on traditional 2D pattern drawing methods. 3D methods have been introduced for personalization but has is not yet implemented for the design for larger populations. This research provides a 3D anthropometric framework that assesses the natural body shape variations within a given user population. The focus is on gaining the highest level of coverage through determining the right body type classification. As a result, digital mannequins are created that can serve as representation of body types associated with specific apparel sizes. This research addresses the sizing of wetsuits for the European market through a full body 3D anthropometric analysis of over 2000 surfer-like body scans from the CAESAR database. Furthermore, different methods are investigated in classification of body types considering the prioritization of different anthropometric dimensions. The resulting population is divided in groups that would be suitable for a specific wetsuit size. These groups are merged into average and extreme 3D mannequins that can be used in 3D apparel design software such as Clo3D or Optitex. The approach is demonstrated on Italian and Dutch subjects with the goal to pro-vide a good coverage for the European market. It can be trivially extended to other populations when suitable data is available.

Keywords: 3D anthropometrics, wetsuit, digital mannequins, sizing system.

1 Introduction

Within the world of wetsuits, the fit and performance of a wetsuit play a critical role in the level of comfort (Naebe et al., 2013). Wetsuit brands are constantly trying to optimize the fit of their designs to better match the customer population. Yet little is known about the anthropometry of the users. European guidelines, such as EN 13402[2], can serve as a good basis for the sizing of garments. But this standard is based on traditional 2D measurements providing a coarse description of shape and size of the human body. With modern technologies such as 3D scanning it is possible to gain more insight in the complex surfaces of the human body (Robinette et al., 1999). Different studies have been performed showing the opportunities in the creation of wetsuit patterns using 3D scans and 3D flattening methods (Naglic et al., 2016; Naglic et al., 2017). Yet these studies focus on diving wetsuits with the use of individual 3D models. The methods have yet to be used in the design for a larger population. Digital simulations have shown its potential in testing both static and dynamic fit (Wu et al., 2017). Wu et al. assesses the dynamic fit by analyzing static poses. This study will investigate the use of motion tracking to assess the full motion during the wetsuit design process.

The goal is to create digital mannequins that can be used for the creation of wetsuit patterns for the surfing industry. These mannequins will give insight in the anthropometric differences of the intended user population between the different wetsuit sizes. These models might also be used within pattern creation software to design for an optimal fit. The models are created based on the current sizing chart of the wetsuit brand SRFACE[7]. They sell wetsuits focused on European males between the age of 18 and 45. For the creation of mannequins a distinction should be made between people who should fit in a standard size (S, M, L etc.) and people who should fit in a tall (ST, MT etc.) size or short (MS, LS, etc.) size. The height distribution for these sizes is used as basis for the creation of mannequins. This will give insight in the anthropometry of each individual size. The research question is: How can we generate 3D anthropometrical data that serves as representation of the user population for the creation and assessment of wetsuit patterns.

2 Method

The CAESAR[3] database has been used as a representation of the user population. It contains measurements and 3D scans of 3 different populations. A Dutch population with n=1267, an Italian population with n=802 and an American population of n=2387. The scope of this research focuses on the European market as a whole. Table 4 contains the percentile height values of the current SRFACE sizes compared to the different CAESAR populations of men between the age of 20-45 years. The Italian and Dutch CAESAR population has been used as a representation of the intended user population. By using both data collections, a more gen-eral population distribution is acquired.

Table 1. Height percentiles of the male Dutch and Italian CAESAR subjects between 20 and 45 years old.

Ad-hoc	*Height (mm)*	*NL*	*IT*	*NL+IT*
XS	1680	P3	P19	P11
S	1730	P13	P48	P29
M	1770	P26	P69	P45
L	1810	P46	P86	P64
XL	1840	P58	P93	P74
XLT	1890	P80	P92	P88

The body scans within this database were used for the creation of three different mannequins for each wetsuit size. A mannequins that represent a general body type of an average user. And two extreme mannequins that represent body types with the highest and lowest body volume that should still fit the same wetsuit size (re-sults not shown). To create accurate mannequins a selection was made of body scans that classify as a certain garment size. Creating an average body out of multiple 3D scans eliminates the characteristics of the individ-ual scans and will focus the mannequin on common body shape features within the size group.

Body types of people that would most likely not be surfers should were excluded. This resulted in mannequins which are more specific for the target population of surfers. Three different approaches were applied for excluding body types based on the paper based on the work of Barlow et al. (2012). Barlow made a distinction between 3 different surfer categories; professional, intermediate and junior surfers. The junior population, with the age of 15±1 years, were not taken into account. The Quetelet index (Body Mass Index, BMI) was used, for it has a high correlation with body fat percentage (Revicki et al., 1986) and could be calculated with the measurements in CAESAR (Robinette et al., 1999). The results of Barlow et al. (2012) for the subscapular skinfold, triceps skinfold, and BMI were used as criteria. The criteria were set to exclude the top and bot-tom 2.5% of the surfing population. This resulted in the following criteria for excluding body types of non-surfers: body scans with 19<BMI<29, 0<Subscapular Skinfold<20 and 3<Triceps Skinfold<17 will be included for the creation of mannequins.

The resulting population represents possible surfer body types. The most important measurements used in the wetsuit industry are height, chest and waist. In the CAESAR project these dimensions have been measured for every individual. But measured waist is the preferred waist relating to the preferred height at which trousers are worn in the waist area. Within the surfing industry the waist is measured as the thinnest waist located just above the belly button. For the classification, only the height and chest were used, with the height as primary dimension and the chest circumference as the secondary. The sizing chart of the wetsuit brand SRFACE (2019) was used as reference where different classifications were addressed based on chest coverage while keeping the height coverage consistent. Dined[10] was used to map out different classification methods on top of a 2D scatter plot of the height and chest circumference. To enable the combining of body scans New 3D meshes of the CAESAR body scans have been generated in Wrap 3[11] using template wrapping. This resulted in 3D meshes with a consistent amount of faces. The sizing groups resulting from the classification method were then combined into an average body type using Paraview[12].

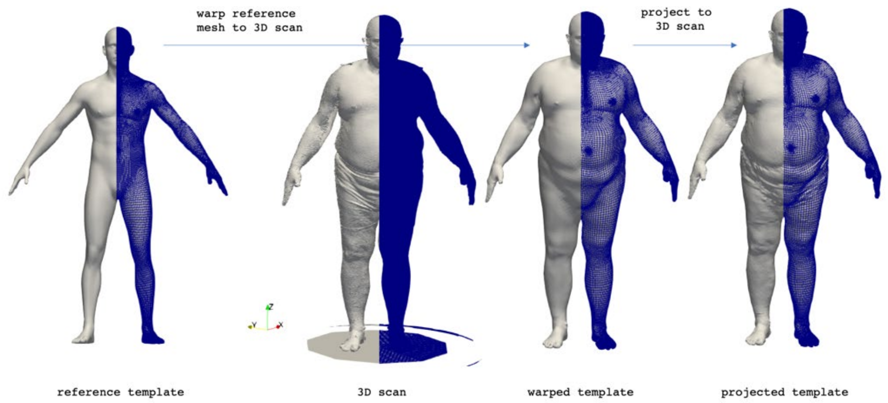

Fig. 1. Template warping workflow.

To be able to test not only the static fit but also the fit during motions (dynamic fit) of garments the static mannequins were animated. Different surfing motions result in different dynamic fit requirements. A selection of surfing motions were captured using the Noitom Perception Neuron[13] to enable designers to analyze a wetsuit pattern. These motions consisted out of, sitting, paddling, duck dive and the pop-up. The pop-up motion incorporated the overall stance on a surfboard. These motions were added as skeletal animations to the medium mannequin.

As a last step, a new wetsuit pattern was created using Clo3D[14]. During this step the usage of the mannequins was put into practice. The new pattern was created in Clo3D based on the current 5/4mm medium sized SRFACE wetsuit (2019). Different types, thicknesses and lining combinations of Neoprene were tested on their physical stress and strain behavior using a tensile tester (Zwick/Roell model Z010, Germany). The results were used to generate digital materials in Clo3D to enable stress and strain simulations of the pattern. The static and dynamic fit were analyzed using the 3D stress and strain maps of Clo3D.

3 Results

Figure X shows the sizing distribution mapped on a scatter plot of chest circumference and stature for the combined Dutch and Italian populations. The plot shows a configuration where the standard sizes (XS, S,M,L, XL are located on the average chest circumference within a given height range. The tall (ST, MT, LT) and short (MS, LS) sizes are located next to the standard sizes with an offset of 3 cm. This distribution has a coverage percentage of 55%, an overlap of around 7% and a chest coverage ranging from 86-104cm.

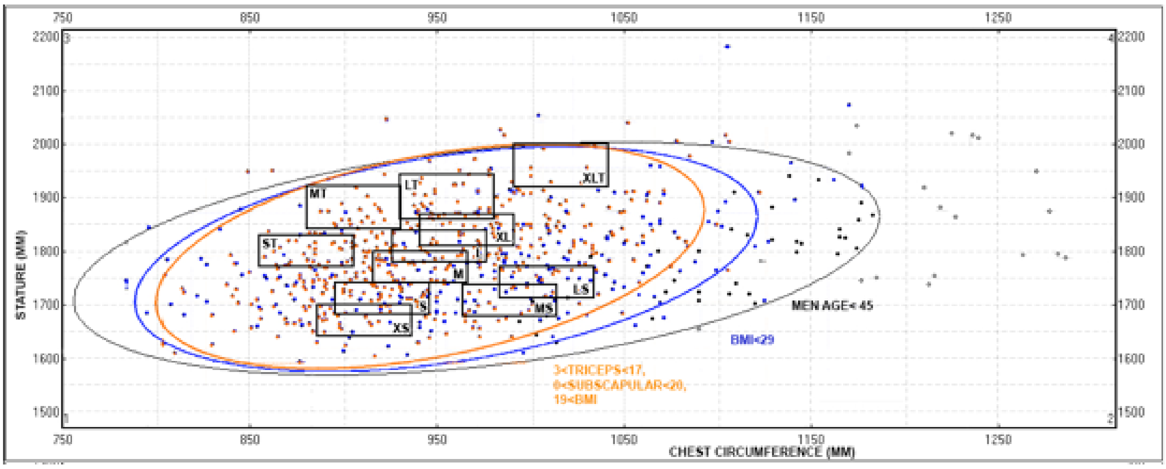

Fig. 2. Classification method used for the creation of mannequins.

Using the classification shown in Figure 2, the CAESAR population is divided into sizing groups. Figure 3 shows the average mannequins created using the average based classification method for the standard sizes ranging from XS to XL, tall sizes ranging from ST to XLT and short sizes ranging from MS to LS.

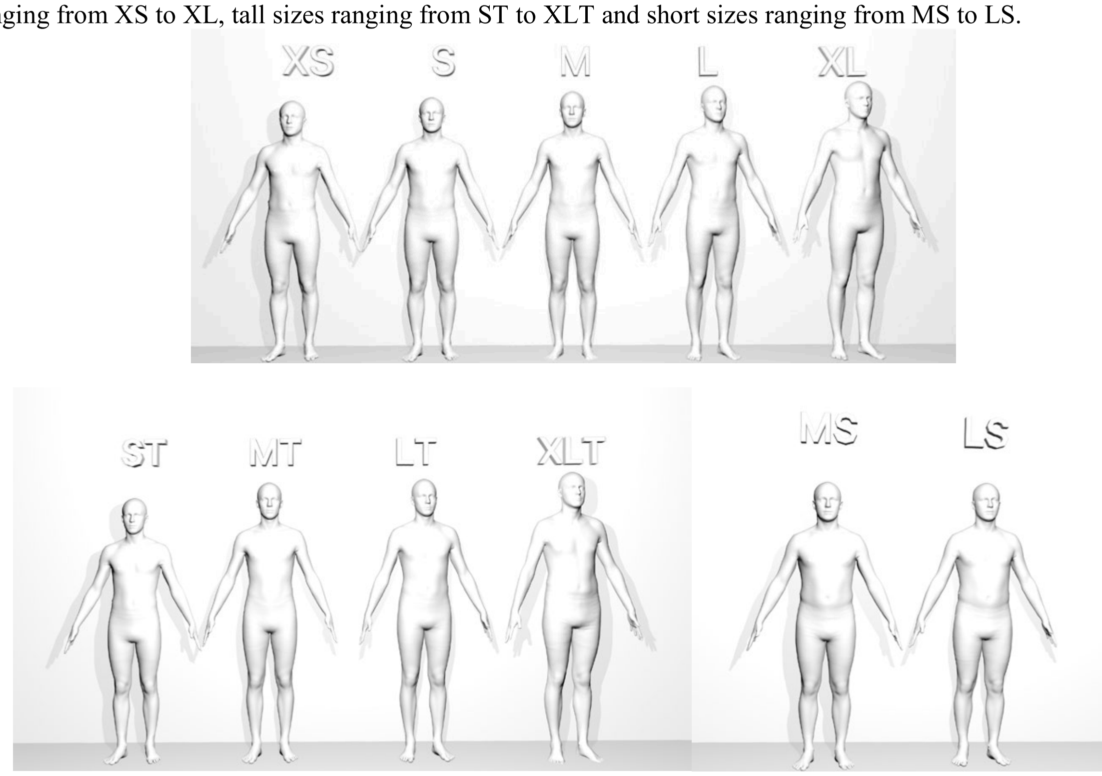

Fig. 3. Average body types for individual sizes.

The medium mannequin has been animated with 4 surfing motions and used to digitally assess the fit of the during the design process of a medium SRFACE wetsuit. Figure 4 visualizes the design process together with the strain mapping of the stretched percentage throughout the wetsuit. Both a static and two dynamic simulations are shown together with the physical prototype. The mannequin shown in figure 4 is created in Clo3D by wrapping the standard mannequin on the medium mannequin shown in figure 3. The resulting mannequin has the same anthropometric dimensions and has been used as demonstration.

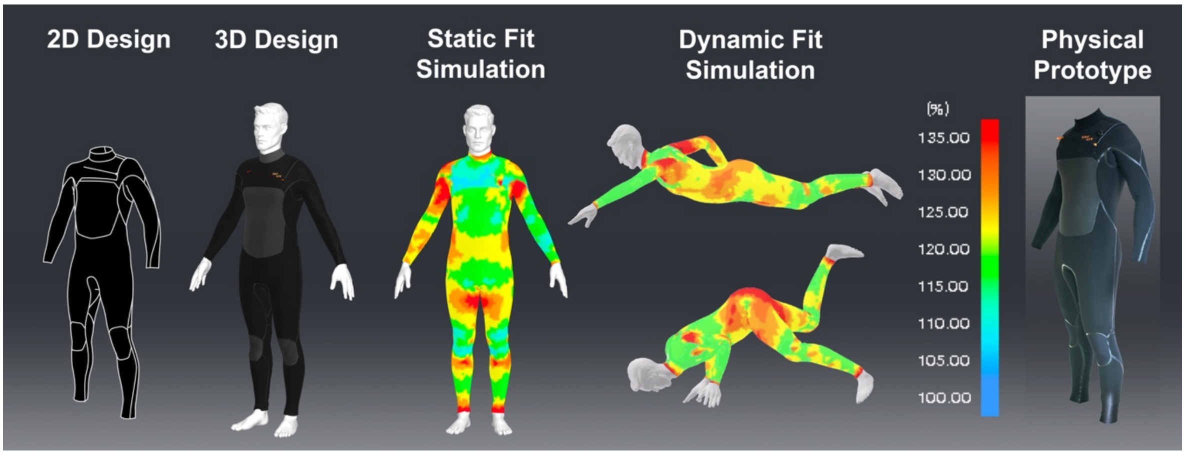

Fig. 4. The different stages of the wetsuit design process.

4 Conclusion & Discussion

The creation of the prototype is done by a designer with no prior knowledge on pattern creation over the course of a couple of weeks. The fit and comfort of the prototype have been assessed by two surfers with a medium body type. Their overall judgement on its comfort turned out to be positive. So the preliminary results show that the use of the 3D mannequins has promising potential for the creation and assessment of wetsuit patterns. The first impression is that this method gives a more readily available design of wetsuits, that may need only minor corrections. It shows potential in reducing the amount of physical prototyping needed to create a finalized product. This can save a lot of time and costs. This is quite a contrast to existing methods for wetsuit design.

Because the prototype is designed for a population group and comfort is a subjective experience, assessment should be made on a larger scale with the use of customer satisfaction and feedback. This step has not been performed inside this study. Based on a primary and secondary dimension a mannequin can be created giving more insight in the overall anthropometry of the users of a specific garment size. The use of such mannequins could be extended to other markets. Any bodily measurement can be extracted from these mannequins for any type of garment.

There are a lot of different classification methods that could be used in the creation of mannequins. Coverage range, market consistency, EU standard consistency and overlap between sizes are important considerations when creating a sizing distribution. The classification method used for the creation of mannequins serves as an illustration. It deviates from sizing charts used in the current market. Using a more consistent distribution will cause less confusion for customers who expect sizing consistency between brands.

The animations captured by the Neuron motion capture suit needed manual adjustments to eliminate artifacts in the motions. The motion capture device used in this work is sensitive to magnetic field disturbances such as caused by metal objects in the vicinity of the subject. In future work, we will eliminate metal objects from the motion tracking environment for improved accuracy. Furthermore, the deformation of the mannequins during these motions should not be seen as accurate human skin deformations. The resulting fit analysis should be seen as approximative simulation. Further work could investigate the opportunities in 4D scanning, weight painting, and muscle-centered skin deformers.

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