Efficient Virtual Garment Fit Evaluation Infrastructure based on Synthetic Avatar Target Customer Groups for MtM Application

Michael ERNST*[1], Monika BOEHM*[1], Antje CHRISTOPHERSEN*[1]
Guido HANSEN*[2], Ulrich BOTZENHARDT*[2], Bettina SEIDER*[2], Susanne WAGNER*[3]
[1] Niederrhein University of Applied Sciences, Germany;
[2] Avalution GmbH, Kaiserslautern, Germany; [3] Assyst GmbH, München, Germany

DOI: 10.15221/18.241 http://dx.doi.org/10.15221/18.241

Abstract

Customization becomes more and more popular and influences the product development process in apparel industry. In addition to individualize products, the fit of garments is very important for the customization.
Numerous tools are used to take the right measurements, to transport individual posture information and to implement these data correctly into a product pattern based on a predefined construction system. In most cases the mass customization process takes place without a fitting session. Usually fit and design will be checked in a very last process step: When the product is already manufactured.
Garment simulation with human avatar-model integration have found its application fields in the fashion industry replacing real try-ons by virtual try-ons with respective savings potentials. Especially when systems become very complex, with high requirements of quality like in MtM scenarios, when there are dozens of technical parameters and decisions and rules defined that influence the pattern / fit of the clothing there is a high need to systematize the validation of the overall system.
Virtual product development is a powerful tool to change this process getting an early fit and design check. Putting together the knowledge of the 3D shape of the human body with the distribution of body-measurements, interdependencies and proportions and feeding this consequently into the process chain consisting of fit prediction / CAD with garment simulation is therefore the basic idea behind the system to be presented. By using an avatar test population representing the target group aimed for it is possible to check the sizing and to screen the fit of a product on individual bodies and postures in a quite short time to validate the MtM grading.
This paper presents a practical approach on the way to implement a virtual fitting session to a mass customization product development process chain.

Keywords: mass customization, body scanning, avatar test population, 3D simulation, virtual product development, virtual garment fit

1 Introduction

The shape of the human body is individual. A wide range of body types and measures can be observed. Pattern systems that aim to produce good fit, even more MtM systems that promise to provide a good individual fit for a really wide range of potential customers are critically, in any case expensive to evaluate.
This typically leads to two extreme situations during operation time. Some systems conservatively stay completely unchanged during operation (never change a running system) and therefore potentially have a suboptimal success in the market. Other systems are constantly changed while being productive with respective high risks that these changes may only focus on the latest short-term adjustments. Although obviously introduces with the best intentions these changes may have unwanted negative side effects or even destabilize the overall system.
To prevent such situation it is therefore essential to validate and optimize such complex systems in advance of going live. If changes are needed and the system is productive already it is important to have an instrument that somehow widens the perspective, depicting side effects of modifications and by that helping not to degrade the systems overall performance.
Therefore it is of essential importance to have a simulation system available that reduces these risks by virtually validating the system or its behavior on a wide range of body types (given by so called “avatar test populations”), specifically designed for an individual target group or covering a wide range of customers for improving size sets in garment industry.

*michael.ernst@hs-niederrhein.de, +49 2161 186-6080; *monika.boehm@hs-niederrhein.de;
*antje.christophersen@hs-niederrhein.de,
*guido.hansen@avalution.net; +49 631 343590 10; *ulrich.botzenhardt@avalution.net; *bettina.seider@avalution.net;
*susanne.wagner@assyst.de,

2 Technological Approach

Fit is the most critical part of a successful "made to measure" process in garment industry. Often the individual fit will be established by using a second grading, called MtM grading. MtM grading means an additional grading process based on the standard grading. First the reference size will be assigned, then the MtM grading will be used. The structure of MtM grading requires a lot of effort, because with each customer there occur different values and especially different combinations of body measurements.
An overview of the technological approach of the iMtM process is shown in figure 1. The iMtM process chain starts with the generation of avatar test populations connected via an innovative BatchSimulator with a garment simulation system resulting in a viewer offering a new approach of fit evaluation.

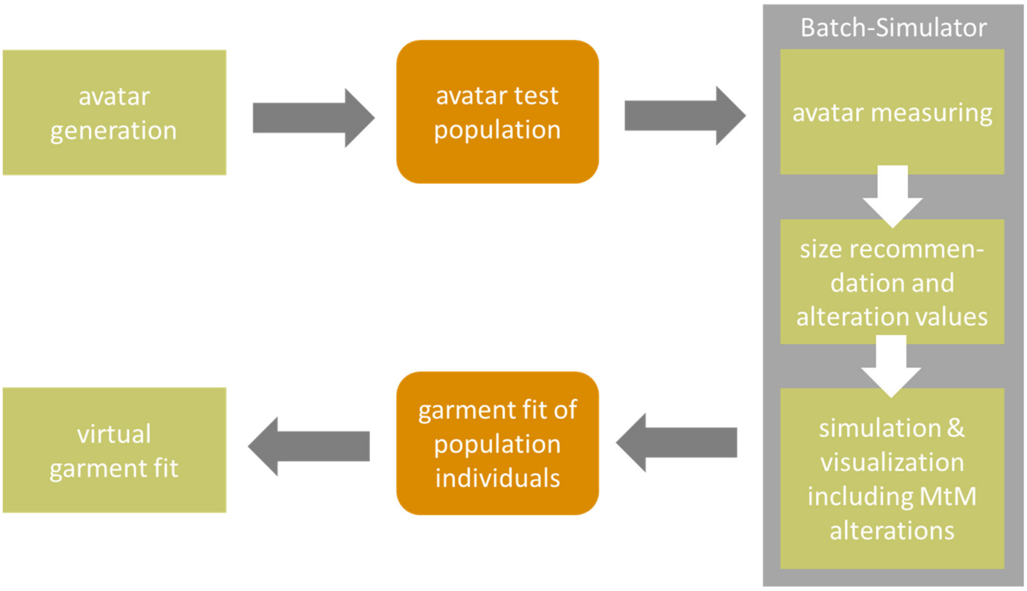


Figure 1: Overall Process Chain

2.1 Definition and synthesis of the target group

Primarily the technology presented in this paper is based on the so called AvatarStudio technique. This technology currently drives the avatar-generator "AvatarTool" in Vidya. In the "Vidya"-implementation it enables the generation of 3D avatars by using typical standard body measurements. The technologies "3D-side" is based on a PCA (principal component analysis) approach using all the 3D- scan material (>>10k Scans) acquired within the serial measurement SizeGermany. It is beyond the aim of this paper to present the working principles in depth of PCA and its theory, but it is important to understand that PCA in some way acts like a learning methods thereby causing an extreme data compression. That means AvatarStudio uses the most important aspects of the 3D forms and thereby has "learned" the main aspects of how the geometry of people looks like. In this specific application case we use 100 principal components. With every principal component having approximately approx. 500k 3D-vectors this gives us the ability to use a relatively compact representation of the most important aspects of the 3D data observed in the serial measurement. The data structure used is approx. 0.5GB in size for each gender. That means it can be held entirely in computer memory during runtime, resulting in a very fast and interactive avatar generation mechanism (~20ms per avatar generation).
Another positive side effect of the compression aspect is that the output can always be guaranteed to be anonymous, which is very important nowadays.
Another positive side effect of using the PCA technology is the fact, that the output range is not necessarily limited to forms observed, filling the "holes" in between observations and also enabling reasonable outputs in regions beyond the observation range e.g. for more extreme types of bodies.
Of course, PCA is only the basic component of the AvatarStudio technology. The technology also uses other (statistical and mathematical) approaches to compute the concrete linear combination of eigen-values to generate a specific, valid and accurate avatar output.

The example below shows avatars for size DOB 40, and HAKA 106, defined on 22 typical measurements of a size chart used in industry.

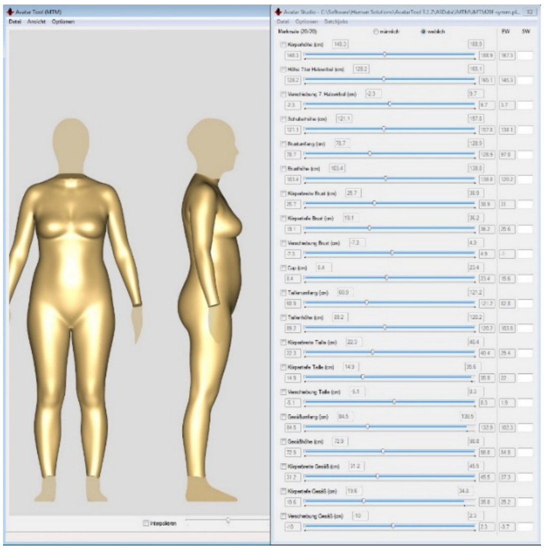


Figure 2: AvatarTool

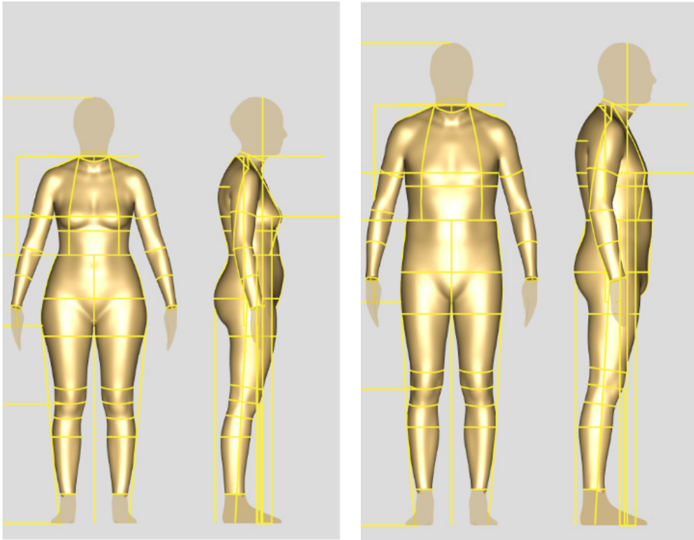


Figure 3: Female and male avatar based on 22 measurements

2.1.1 Avatar Concept

The design of the specific MtM avatar controlling measurements, more specifically the selection of the so called features or feature-vectors (general term for the sum of parameters defining an avatar) is intentionally oriented towards typical dimensioning rules like in mechanical- or civil engineering (technical drawings).

Circumference-measurements are consequently equipped with a height component. The specific proportion of each such segment can be configured in more detail by its width- and depth. Equipped with all these input parameters a large range of body-types/ and morphological aspects can be expressed and explored systematically.

The example below shows two avatars, generated from the exact same body measurements (HAKA 106S), with the morphological variation like triangle and inverted triangle.

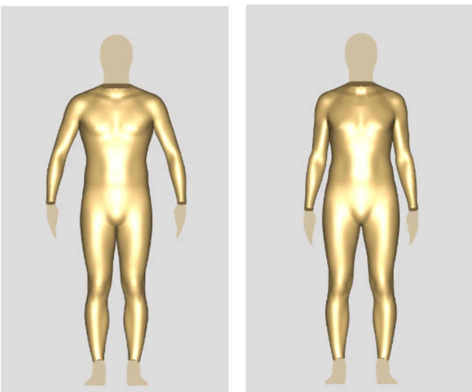


Figure 4: Male avatars same body measurements but different morphological shape

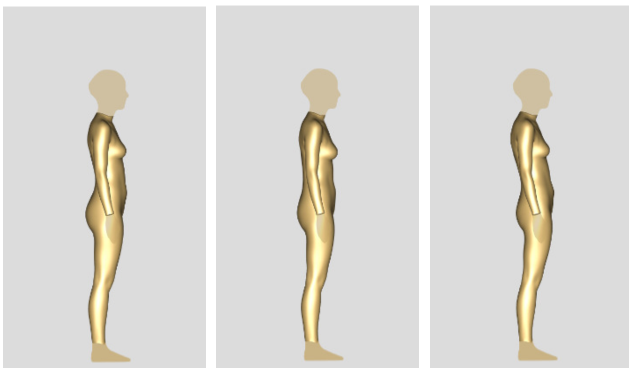


Figure 5: female avatars vary in shape and posture

In addition to that, special features had been introduced that control typical postural aspects to e.g. examine to which extend a specific body (/size) given by its measurements may still vary in its shape and posture, and to what extend this affects the fit.

2.1.2 Avatar test population set up for garment fit testing

The knowledge about body measurements, body morphology, posture etc. of prospective customers is an important requirement to ensure the garment fit – especially for MtM products. Therefore the fit has to be checked during the product development process, and not before the product is already manufactured. To allow the fitting for a number of various bodies, the use of a suitable software application is needed. By means of such a software a large avatar test population can be generated and an early testing procedure is possible.
The avatar test population consists of avatars, which represents as many as possible prospective customers with their individual bodies. Based on body measurements as well as the distribution of girth measurements it´s possible to generate these different bodies. Avatars with particular postures e.g. hollow back or asymmetrical body shapes allow an early fitting for high-level MtM products.

Following the requirements for AvatarTool application are described:

<u>Accuracy</u>
The most important requirement for the avatar generation engine. This means that at least in respect to the explicitly given input features (e.g. traditional body dimensions) the output of the avatar needs to be 100% accurate in respect to its measurements.
The avatar engine fulfills this “100% accuracy” requirement by a sort of a closed control-loop technique to its measurement-score value computation stage.

<u>Validity</u>
Statistical validity of the 3D shape of the output in general is more difficult to prove than to create, but if something is visually not plausible it is a clear sign of invalidity. Invalid input (measurements) will most probably lead to obviously implausible output. To achieve this, the AvatarStudio normally operates in a standard-mode where the setting range of the input features directly correlates to the statistical observed values and intercorrelations (taken from a serial measurement like e.g. SizeGERMANY). This means, the scope of global ranges and the multidimensional dependent expected values plus the setting ranges of the features always stays reasonable/correct and generate only valid 3D avatars. The big advantage of this mode of operation is, that the end user benefits directly from the knowledge during the definition of an avatar test population without the need to bring in own knowledge or taking risks in relation to the validity of his investigation.

<u>Wide range of operation</u>
It must be stated in general that the need to express or model individuals always contradicts the statistical validity tests somehow. Nevertheless there is also the need to have statistical shaped avatars with a large amount of individual body measurements e.g. taken from an individual person.
Another requirement is to produce avatars for specific size tables. Sometimes the extreme sizes in size tables are intentionally conservatively, to have “something” on the edge or even beyond of the range of observation.
To support these needs a second mode of operation in the AvatarTool offers a much broader working range concerning measurements and their correlation. This mode lets the user produce highly individualized avatars.

<u>Compatibility with garment-simulation</u>
Obviously in this sort of application the output needs to comply with the technical needs of the used garment simulation system. This specifically often permits body part intersections which may happen in the slit regions where garment simulations typically behave critical anyway.
The AvatarTool therefore has a fully automatic intersection detection and modeling stage build in. In a few cases, this remodeling takes place in regions where it interacts with body measurements (e.g. bust girth, thigh girth). Therefore the slit modelling in AvatarStudio takes place inside the closed control loop guaranteeing the output being always both: 100% accurate and sufficiently slit modeled to comply with the cloth-simulation.

2.1.3 Avatar generation process on predefined values

The challenge of having such a very sharp working technology needs also to be mentioned. Especially while handling large input vectors the outcomes conformity to expectations highly depends on the correctness (precision) of the input values. For the reason of size charts being often a slight compromise between tradition (e.g. existing size tables) and esthetical requirements of the “numbers” they are is not a true 100% valid function of the underlying data and may have slight inconsistencies that now come into focus.

For several reasons it is possible that an Avatar defining measurement vector is somewhat off, or expressed in more aggressive terms is faulty that in combination with the amount of partially redundant or dependent measurements this may lead to inconsistencies on a fine grain level that in former times no one was able to “see” and probably seldom caused problems.
AvatarStudio always guarantees the output to have 100% correct measurements. Anyway the example below simulates the effect of having an error of +3 cm in the back length measurement on the avatar generated (right side).

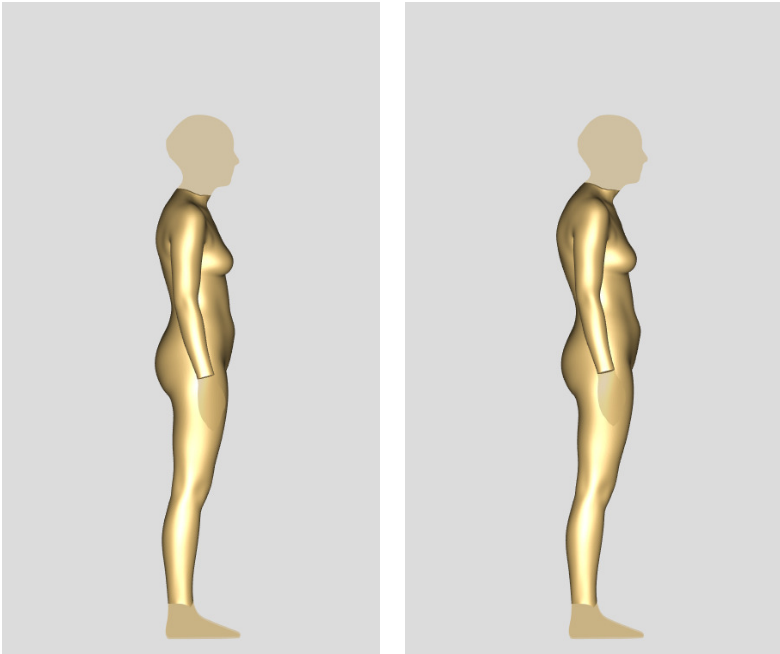


Figure 6: Change in posture forced by body measure back length

Base is an avatar defined by 22 measurements taken directly from DOB 38 size chart (left image). The reason for this behavior is that based on these 22 measurements all heights and circumferences are more or less already defined, and the assignment of +3 cm for back length is only possible by changing the posture.
It is therefore recommended to specify an individual avatar on the input vector side by using the engines integrated statistics for the prediction of the most probable avatar shape.
In the following example a female Avatar is produced by the following measurements: body height, bust, waist and hip circumference taken from size DOB 38.

body height: 168 cm
bust: 88 cm
underbust: 74 cm
waist: 72 cm
hip: 97 cm

body height: 168 cm
bust: 88 cm
underbust: 67 cm
waist: 72 cm
hip: 97 cm

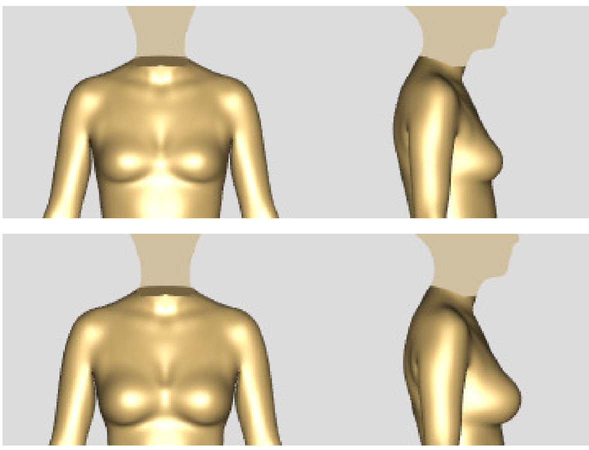


Figure 7: Effect of changed bust/underbust circumference by -7cm of female person

2.2 Garment simulation on avatar test population for developing MtM systems

The use of garment simulation on avatar test population offers the possibility to validate the MtM grading process and by visualizing the simulation results enabling the user to approve size, fit and design.

2.2.1 Automatic creation of an avatar test population with automatic measurement creation and output for MtM

From an architectural point of view the system consists of 3 major components:

1. the avatar test population definition system (AvatarTool)
2. a batch executing system including (BatchSimulator)
   - avatar measuring
   - size recommendation and calculation of alteration values
   - a garment simulation (Vidya) system in combination with a CAD system including MtM functionality
3. result viewing and simulation comparison system (SimulationViewer)

As a means of expressing the different simulation results and its effects a series of screenshots are taken showing the rendered result and also (configurable) pseudo color images for different physical aspects: texture, body distance, pressure, stretch

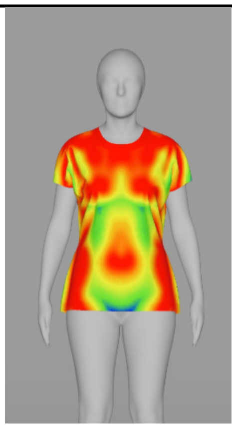
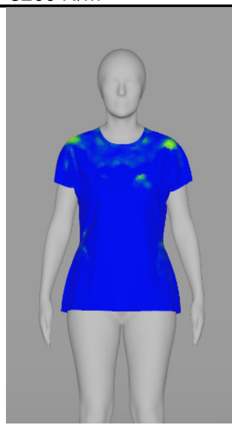
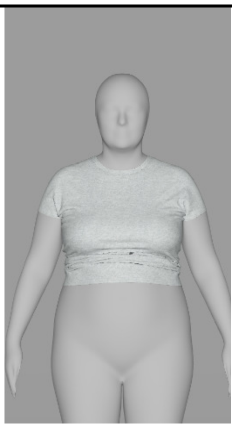
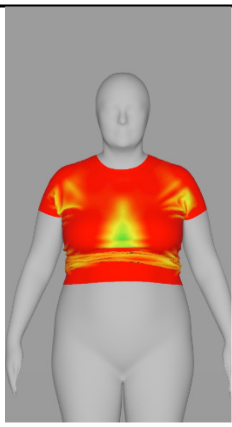
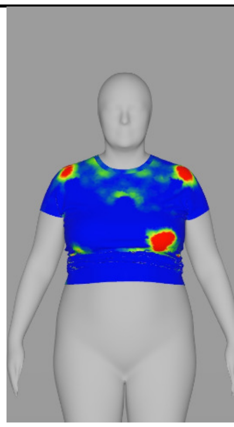
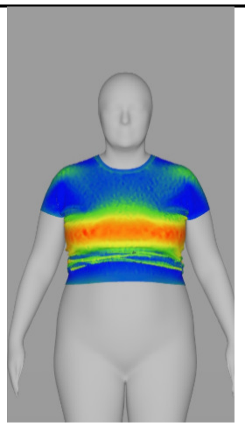
	Textured rending: Garment is shown with its real fabric texture	**Distance:** Distance between body and garment is shown from blue - distance +4cm - to red - no distance -	**Body Pressure**: Body pressure resulting from inner forces of the garment is shown from blue - no pressure - up to red - pressure of 3200 N/m² -	**Stretch**: Garment stretch is shown from blue - no stretch - to red - significant stretch -
T-Shirt size 38, Body size 36				
T-Shirt size 38, Body size 44				

Figure 8: Four views of results in different physical aspects without alterations of garment too loose and too tight

2.2.2 Definition of the avatar test population

The avatar test population definition is performed and integrated into Human Solutions AvatarTool application, special version for the funded project iMtM, to explore different aspects of homologous avatars. The AvatarTool itself incorporates in different ways the import homologous avatars. Typically these avatars come from the so called AvatarStudio engine (also integrated into Vaidya's AvatarTool), providing functionalities for the generation of statistically correct avatars, defined by body measures e.g. taken from size chart. The technology may also use homologized avatars from other sources like individual persons from 3D body scans. In fact every kind of homologous avatar can be used in the engine as a so called anchor point ranging from statistical avatars (e.g. correlating to a specific size) to individual persons (virtual house models).

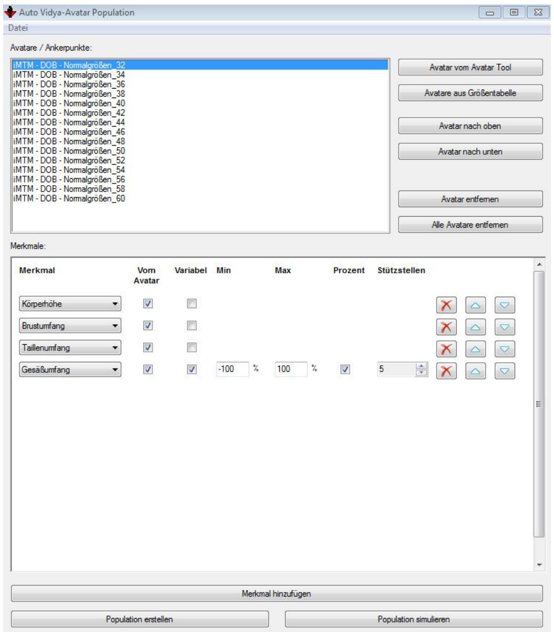


Figure 9: Creation of avatar test population

In respect to the effects (features) of the AvatarStudio engine, every anchor point added (shown in the upper half of the GUI) can be kept constant or can be systematically modified by different rules (shown in the bottom half of the GUI). The execution of the rules on the anchor points form the final output, the so-called avatar test population.
The following example shows the usage of the technology to build an avatar test population on the basis of an individual person's scan for men´s wear 42,48,54,60 (left to right).
Mechanisms are integrated to prevent too similar avatars.

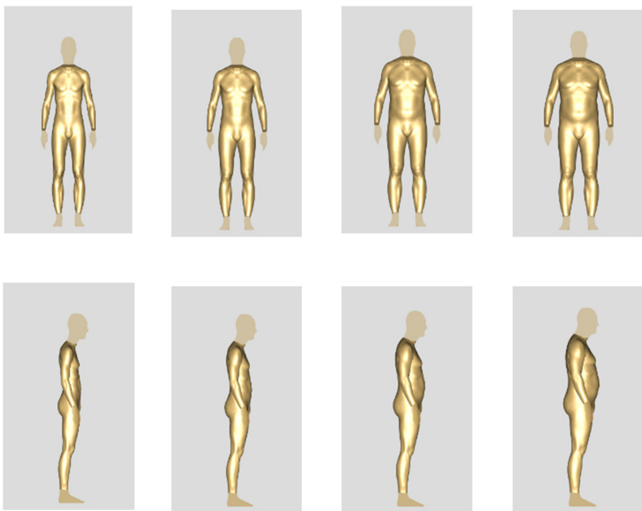


Figure 10: avatar test population (4 sizes)
based on individual persons scan

2.2.3 Batch execution system

The batch executing systems is carrying out a batch of different simulation tasks on the basis of the selected avatar test population. To execute the part of garment fitting, it needs to be able to take out the MtM specific body measurements of the active avatar. The batch executing system provides a GUI so that the user can control all the parameters of the simulation run.
The 3 main sections of parameters are:

- Garment simulation relevant parameters
- Calculation of size recommendation and alteration values
- Configuration of the image parameters

2.2.4 Batch SimulationViewer

The task of the batch SimulationViewer is to visualize and filter the output to the needs of the user. The example below shows a typical usage scenario:

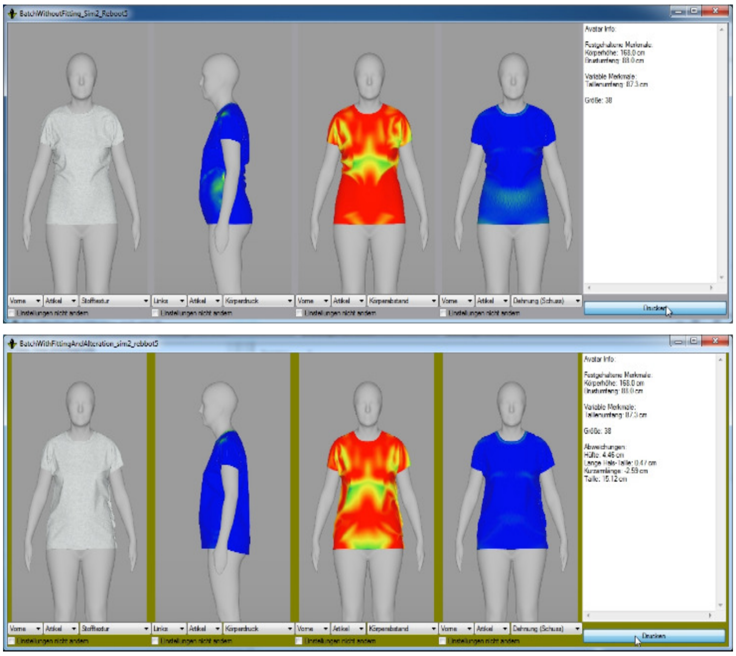


Figure 11: Upper and lower SimulationViewer with garment with and without alterations on same avatar

The upper window shows the situation before two new alterations (changes to the T-Shirt in hip and waist dimensions) are introduced, the lower window shows the effect of the improved fit in direct comparison.

2.2.5 Size chart definition and creation of grading rules for reference sizing

The MtM grading is based on the choice of a reference size. To identify the reference size body measurements as well as garment measurements are needed. The position of body and garment measurement have to be matched, e.g. the bust girth position of the body has to be compared with the corresponding position in the pattern. Main body measurements have to be defined and assigned to priorities. Within predefined tolerances main values and garment values have to be compared in order of the priorities to get the right reference size.

2.2.6 MtM Pattern creation process and MtM grading

The MtM pattern creation process starts with the definition of all individual modifications, e.g. only length modifications (level 1), length and width modifications (level 2) or additional special postures (level 3). Similar to the standard grading MtM rules are defined once-only and can be used for MtM grading of the specific patterns. MtM grading is always used in addition to the standard grading. For a perfect fitting both gradings – standard and MtM - are really important. Therefore the fit of all size has to be checked and perhaps optimized before using MtM.

2.2.7 Virtual Fitting of MtM pattern on avatar test population

Standard MtM-Measurement Set

A standard Set of special 52 MtM Measurements; (overall 76 measurements counted separately for the two body halves) are integrated into the system. The measurement set is conceptually layed out as a unisex measurement set. Measurements are integrated within Anthroscan, and can be computed for an individual scan (e.g. scan coming from 3D scanner) and for Avatars (Avatar batches) coming from the AvatarTool. Prerequisite for the execution is that the avatar is a homologous avatar, which is standard for the avatars coming from AvatarTool. For 3D Scans a fully automatic conversion of a 3D Scan into its homologous form can take place with Anthroscan (e.g. by using the function “Export as homologous Vidya Avatar“.

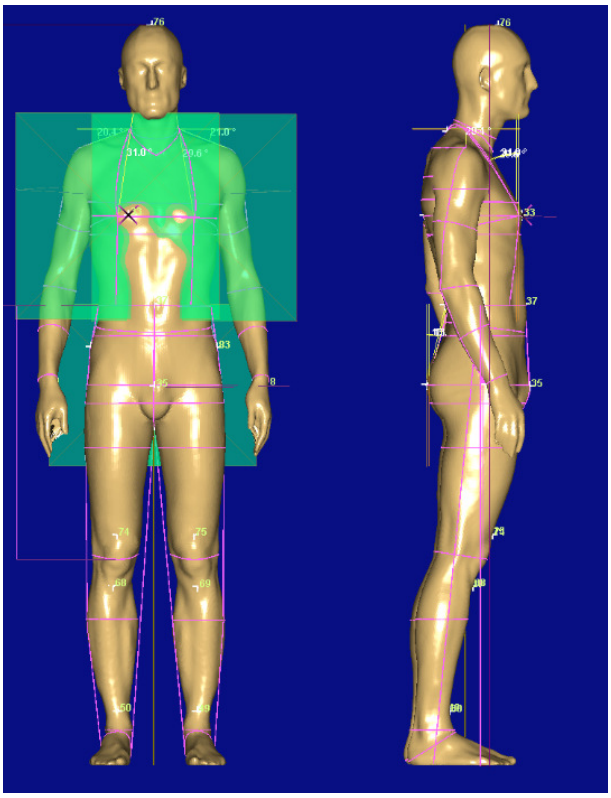


Figure 12: Pictures of iMtM unisex measure set

3 Research methodology

Investigations have been carried out using different MtM products of classic women and men wear as well as workwear.
All products have been fitted and evaluated on the avatar test population with 3D garment simulation applications – Vidya, V-Stitcher – regarding to realistic material simulation following the research methodology shown in Figure 13.

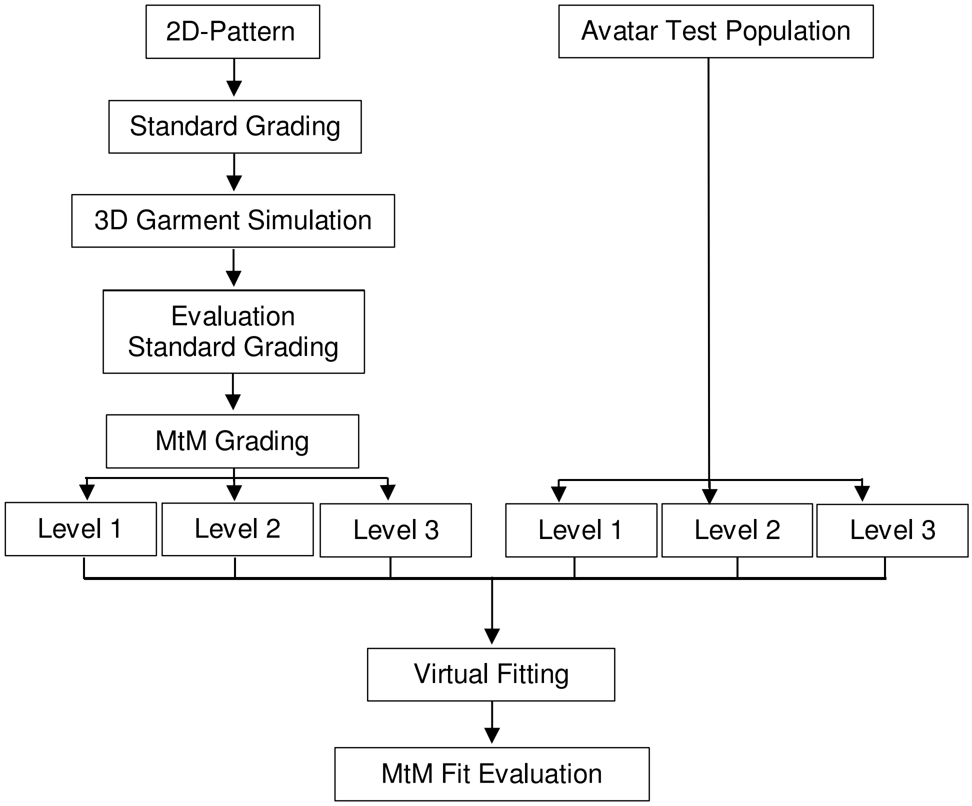


Figure 13: Research methodology

3.1 Target group

The target group for MtM garments is related to the target group of the defined standard sizes. The aim is to dress customers with bodies and shapes different to the standard sizes.

3.1.1 Definition of target group

The target group investigated comprises female and male avatars split into three groups, depending on the predefined MtM modifications:

- Level 1: Length modifications
- Level 2: Length and girth modifications + distribution of girth modifications
- Level 3: Posture modifications

All test avatars based on statistically verified bodies and therefore extreme body data are excluded and not part of the survey. Figure 14 shows a selection of the target group.

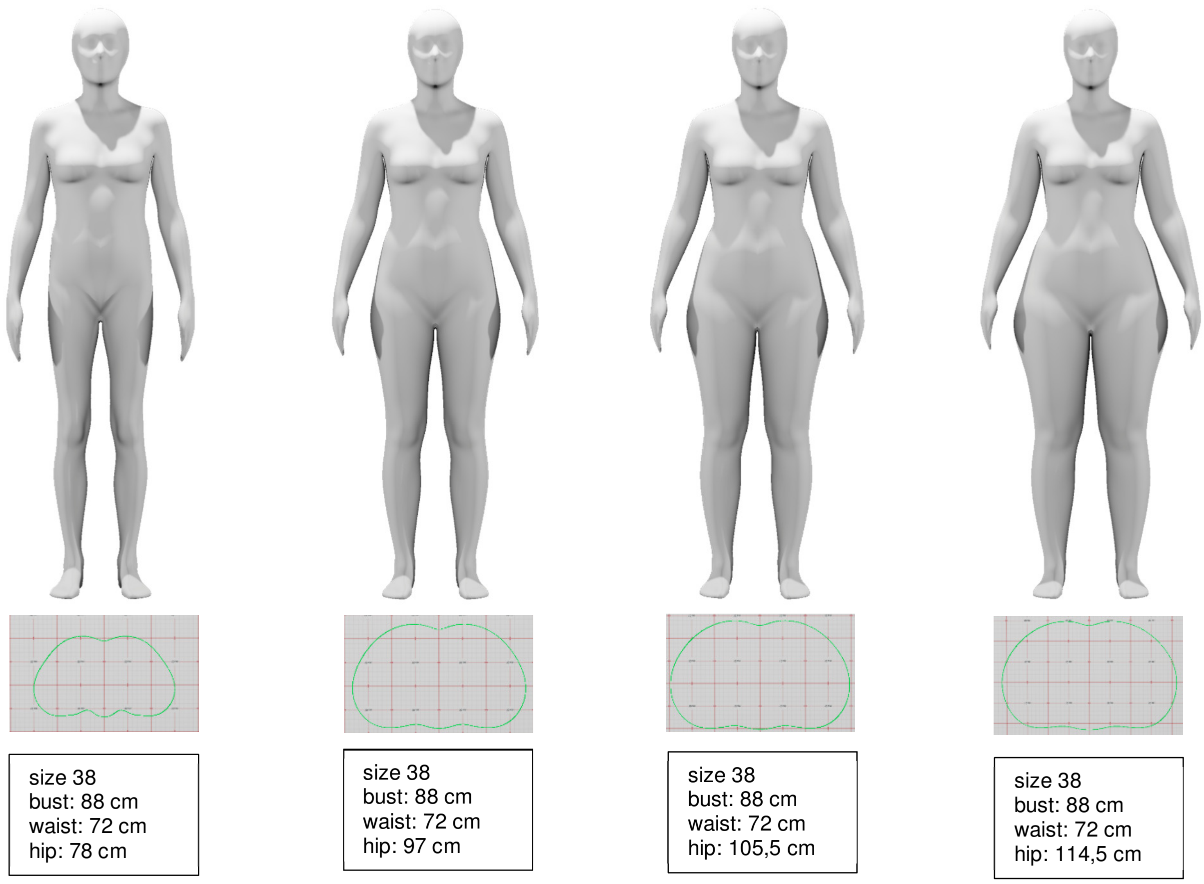


Figure 14: Target group

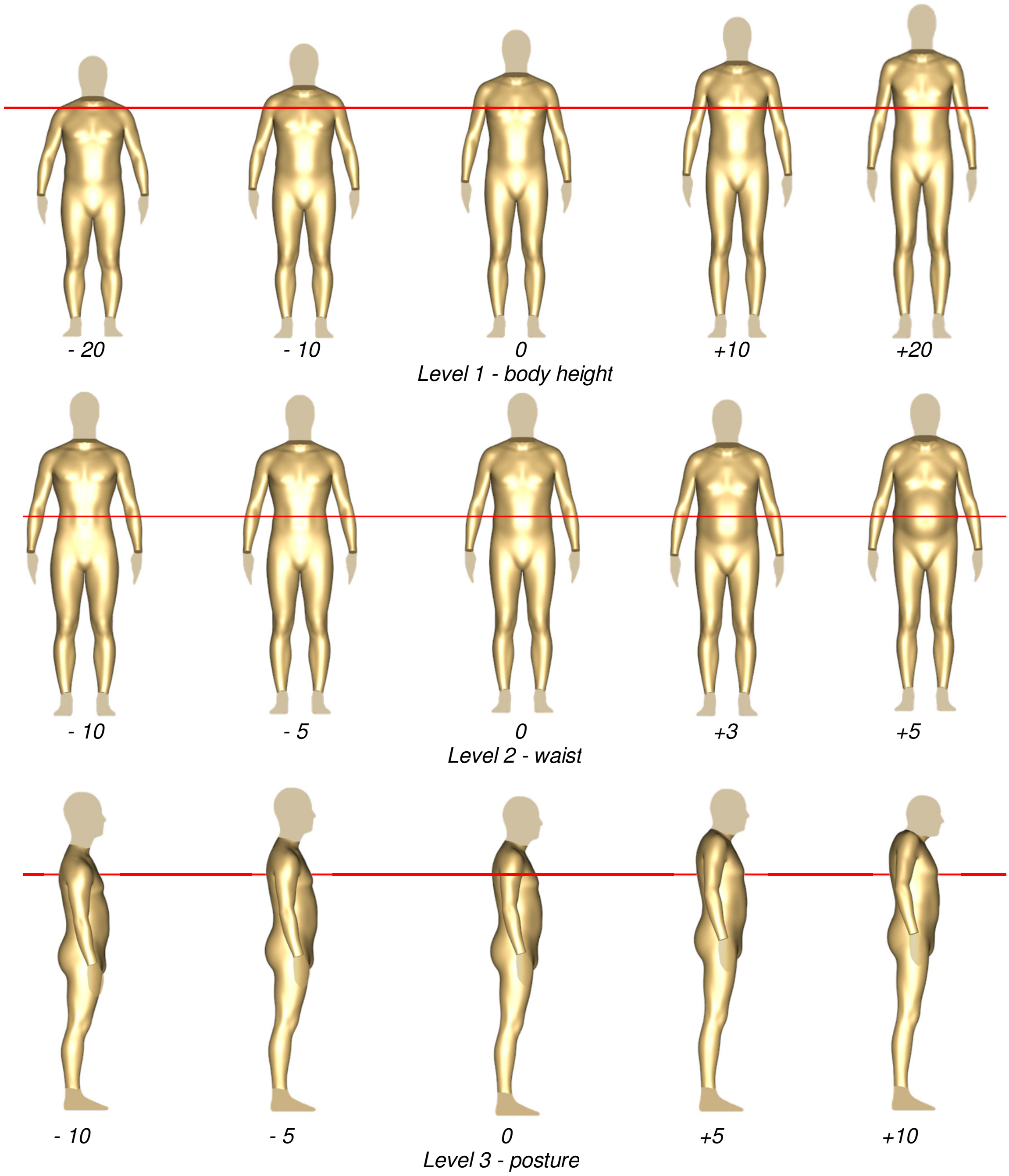


Figure 15: Target group; Level 1 - 3

3.1.2 Size recommendation

The selection of the product-related reference size for upper-body garments is given by bust, waist and hip girth, for lower body garments only by waist and hip girth. Therefor the measurements are rated with different priorities.

3.1.3 Calculation of alteration values

Alteration values are calculated by the difference of individual measurements to the values in the size chart.

Divided into four areas - length modifications, girth modifications, distribution of girth measurements and posture – rules are developed to transfer the modifications directly to the MtM grading process. The overview below shows the different rules for each area.

- Length modifications: difference of individual and standard body measurement
- Girth modifications: difference of individual and standard body measurement, with standard distribution based on the selected construction system
- Distribution of girth measurements: the distribution is measured on the individual body and the difference to the standard distribution is used for the MtM rule
- Posture: comparison of different body measurements, e.g. for a hollow back comparison of neck to waist center back with neck to waist over bust

3.2 Product group

Representative for the investigated products – classic products of skirts, blouses, shirts and trousers as well as workwear products– the results of a blouse and a smock overall are shown below.

- **CAD pattern:** The product development as well as the standard and MtM grading is done for all products with the 2D CAD system Cad.Assyst. A second test with the 2D CAD system Grafis has shown that the process can be transferred to each other 2D CAD system.
- **Basic pattern:** Both patterns – blouse and smock overall – based on the iSize body measurement chart for women from size 32 to 60.
- **MtM Grading**: Based on the reference size the predefined MtM-values will be automatically calculated and directly imported to the CAD System.

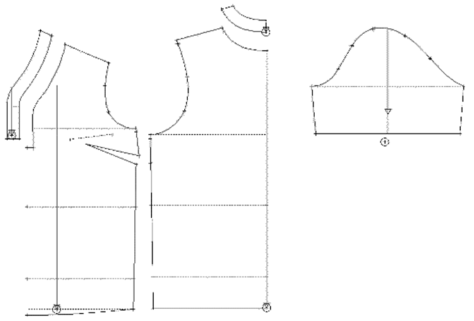


Figure 16: Smock Overall - Basic Size

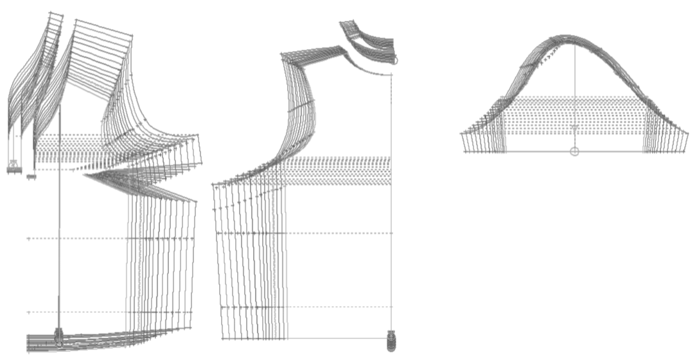


Figure 17: Smock Overall - Grading

3.3 3D Simulation

3D simulations are used to evaluate the fitting in an early state – before starting a manufacturing process. The virtual stitching is done with the 3D CAD Systems Vidya and V-Stitcher to make sure, that a virtual fitting doesn't depend on a special 3D CAD System.

3.3.1 MtM fitting

The MtM fit will be checked for the avatar test population and different products using a batch mode of the 3D simulation system Vidya. The output of different simulation pictures for each single simulation offers the possibility to verify the MtM fit.

3.3.2 Fit evaluation

Figure 18 gives a review about the fit evaluation based on virtual try-ons. Different simulation views like body-distance, elongation, and elasticity give detailed information about the fitting.

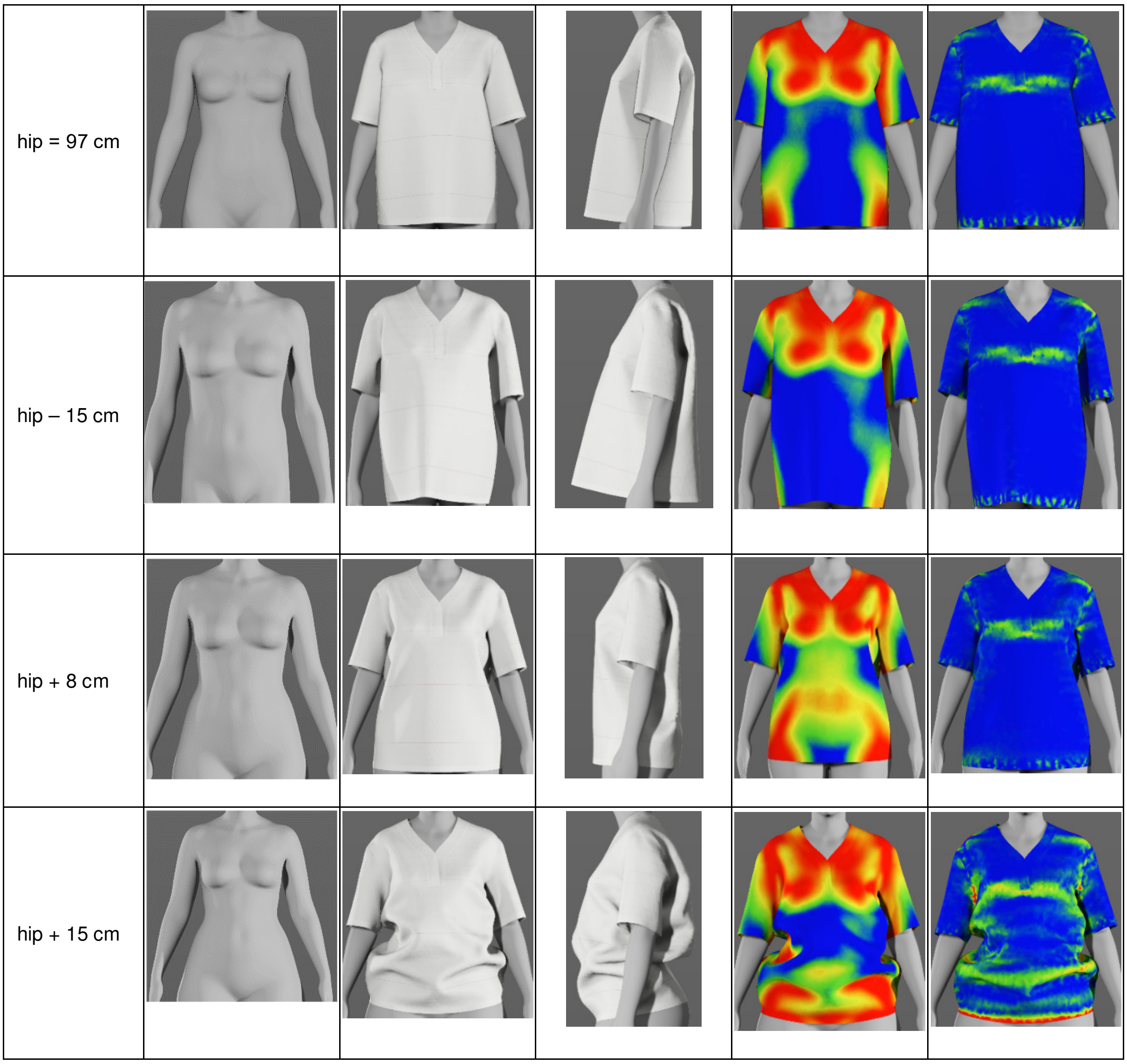


Figure 18: Virtual Fitting of reference size for target group

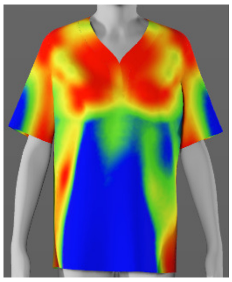
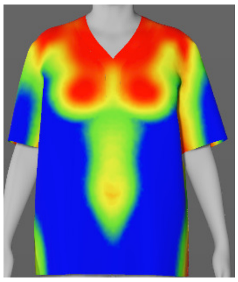
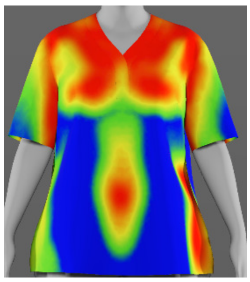
4 Results

The following results are only few extracts from the tests done with a comprehensive avatar test population of females and males and the resulting fittings. They are divided up into the four sections: The generation of the avatar test population, validation of the avatar test population´s measurements obtained from a special software application, approach of implementing posture and shape parameters into MtM pattern construction and 3D Fit investigations for an accelerated pre-check of fit within the MtM process.

4.1 IMtM Design evaluation

4.2 IMtM Fit evaluation

	Reference size	MtM grading	Body distance
hip – 15 cm			
hip + 8 cm			
hip + 15 cm			

5 Discussion and Conclusion

The results of this paper have proven the importance and the benefit of testing the MtM grading in an early state of the product development process. The automatic creation of avatar test population and the batch mode for the 3D simulations are very helpful tools to get the virtual try-ons quickly and available for MtM validation process. Knowing that not all individual subjects can be covered by MtM process, realistic avatar test population for industry application can be visualized and measurement extraction are delivering multiple MtM information. The algorithm to evaluate the size recommendation is highly flexible and can be specified for individual purpose.

Next step to round the complete process aims to simplify the fit validation step by offering an automated and objective rating system for the garment industry.

6 References

M. Ernst and U. Detering-Koll: “*Posture Dependency of 3D-Body Scanning Data for a Virtual Product Development Process”,* in Proc. of 5th International Conference on 3D Body Scanning Technologies, Lugano, Switzerland, 21-22 October 2014

H. Löffler-Wirth: “*Body Typing of the adult population of Leipzig”*; Application forum Human Solutions. Kaiserslautern, Germany, 21 April 2016

M. Ernst and U. Detering-Koll: ”*Investigation on Body shaping Structures Using Body Scanning Technology and 3D Simulation Tools”*, in Proc. of 3nd International Conference on 3D Body Scanning Technologies, Lugano, Switzerland, 16-17 October 2012

M. Ernst: Next *Generation of Product Development- Obtaining 3D Buy-in, Building Capability and Generating a Fruitful Roadmap;* PI Conference Berlin, Germany, 5-6 October 2016

M. Ernst, M. Böhm, U. Detering-Koll: „*Rapid Body Scanning Technology for a Virtual Mass Customization Process in Garment Industry*“, in Proc. of 7th International Conference on 3D Body Scanning Technologies, Lugano, Switzerland, 30 Nov. – 1 Dec. 2016

Allen, B., Curless, B., & Popovic, Z. (2003): "*The space of human body shapes: reconstruction and parameterization from range scans*", *SIGGRAPH '03 ACM SIGGRAPH 2003 Papers* (S. 587-594). San Diego, California: ACM New York.

Blanz, V., & Vetter, T. (1999): "*A morphable model for the synthesis of 3D faces*", Proceedings of ACM SIGGRAPH 99, S. 187–194.

Praun, E., Sweldens, W., & Schröder, P. (2001): "*Consistent mesh parameterizations*", Proceedings of ACM SIGGRAPH 2001 (S. 179–184). New York: ACM Press/ACMSIGGRAPH.

Turk, M., & Pentland, A. (1991): "*Eigenfacesforrecognition*", Journal of Cognitive Neuroscience 3, 71-86.

Fischer T., Artschwager A., Pfleiderer K., Rissiek A., Mandalka M., Seidl A., Trieb R.: “*Automatic morphological classification with Case-Based Reasoning*”, 7th International Conference on 3D Body Acanning Technologies, Lugano, Switzerland, 30.Nov.-1.Dec. 2016