Fashioning Movement
A new approach to Fashion Design

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Abstract
The research project Fashioning Movement explores new fashion design processes by means of new technologies and in particular by means of motion capture, human 3D body scanning and 3D simulation software. In this context, the project generated data and new knowledge about the interaction between the body and the garment during movement: the garment is no longer only deformed by the static shape of the body, but also by the type of motion and related body deformations. Muscles deformations and the direction of the muscle movement are visible in the deformation of the garment and serve as a design element. A new 3D garment shape which is based on the moving 3D body shape has been developed with 2 different approaches: on the one hand, through the 2D pattern and on the other hand, through the use of different fabric qualities and elasticities for different parts of the body. Thus, new garment aesthetics and new functional garment shapes for certain sports can be generated and new perspectives for fashion design can be opened up.

1. Introduction

In Fashion Design, clothing can be understood as interactive envelop or "second skin" for the complex 3D shape of the human body. In the search for ever-new body envelopes various design methods have been developed. Emerging pieces of clothing serve to cover up, to reveal or to accentuate the body or parts of the body and eventually interact with the latter. In fashion history, various epochs of styles are characterized by certain ways to envelope the body. Our current time is characterized by a plurality of co-existing styles, where each look has a different idea about the garment "fit": baggy pants have to be too large, shape wear has to be too tight and a formal men suit ideally has to be tailored made to measure to the body. There is, however, one characteristic that all different kinds of pieces of clothing have, over time or of all styles, in common: their 2D flat pattern and their 3D garment shape are developed for an upright standing body.

At a first glance is seems contradictory and unnatural that the body motion has until today not been taken into consideration in fashion design, as we are rather moving than standing in an upright position. This fact can, however, be explained: on the one hand, existing traditional fitting methods do not allow the assessment of a garment on a moving body. A fashion designer or a clothing engineer can, for example, not follow a person in movement (sports, etc.) to assess a garment fit and place pins to correct overwidth's of a garment or to mark narrowness's. He/she has to rely on the subjective judgement of the fitting person. Only simple movements such as lifting up the arm are possible. On the other hand, the body was traditionally perceived and presented without any motion. Over years, persons were shown on photographs in an erect position [1]. Thus, this visualization of the human body also possibly shaped the image of clothing. Taking into account the body motion, a central aspect of the human body, thus, constitutes a novel approach for fashion design with a high potential for aesthetical and functional innovations.

2. Background

On the one hand, with regards to fashion, clothing and motion, researchers previously mainly focused on the field of clothing physiology. Clothing physiology studies the garment constructions (form and material) with respect to the requirements of the human body and the skin: not too hot in summer, not too cold in winter, ideal moisture and heat transfer during exercise. As the enclosed air layers and contact areas between the garment (or garment layers) and the body are responsible for the heat and moisture transfer, the form of the garment plays a major role [2, 3]. Physiological aspects of clothing can today be simulated. However, within these simulations the body motion only determines how much a person sweats during a certain activity.

On the other hand, some sportswear companies develop first garment prototypes which are adapted for a certain type of sport, such as a ski jacket with additional darts on the shoulder part that imitates somehow the typical downhill ski position. These shapes are, however, preliminary samples, which are not based on real sports movements' assessments.

3. Data generation

Empirical input data was first created in the form of motion fitting data (see Figure 4) as a basis for this research project. To obtain this empirical data, several professional athletes practicing alpine skiing, Nordic skiing and mountain biking were 3D scanned, their movements recorded using motion capture and their virtual bodies animated.

3.1. 3D body scanning and body modelling

Our methodology starts with the modelling of accurate subject-specific virtual bodies of the athletes. Nowadays, 3D human body scanners are used to generate anthropometrically correct size and proportional virtual characters. Contrary to the models generated by 3D authoring tools (e.g., Autodesk Maya or 3dsMax [4]), scanner generated models are millimeter scale precise to the surface details of the scanned subject (accuracy of ~1mm).

In this project, the athletes were digitalized using a photogrammetric 3D body scanner composed of 96 cameras (Figure 1). The idea is to acquire 96 photos at different angles of the subject positioned in the center of the scanner. The main advantage over other scanning techniques such as laser scanners or hand-held devices is that the scan is performed in a single shot. This allows avoiding minor movements of the scanned subject (e.g., during respiration) and therefore achieving more accurate results.

Figure 1: Photogrammetric 3D body scanner with subject standing in A-pose.

For each athlete, a first scan was acquired in A-pose (standing position, arms on the side) and used to reconstruct a 3D body mesh. The 96 photos of the subject were analyzed by the reconstruction software (Agisoft Photoscan Professional [5]) to find corresponding points between the different images. These points were used to generate a dense point cloud of the body. The resulting scan data was then post-processed (e.g., noise reduction, triangulation) and optimized for animation (e.g., resolution reduction, topology optimization) (Figure 2A). To allow the animation of the virtual body, an underlying skeleton with a hierarchical structure was created (Figure 2B). This structure drives the animation of the subject's skin model, which is achieved by attaching model specific skinning information on the mesh based on a dual-quaternion skinning method [6].

To refine the skinning algorithm, additional scans for each sport and for each athlete were obtained in various key postures (e.g., seated on the bike, in skiing position). The scans provided reference key postures to be used in a pose space deformation approach [7]. This approach ensured an accurate skeleton-driven skin deformation by adding an extra layer of animation that locally corrected the dual-quaternion skinning method around those key poses.

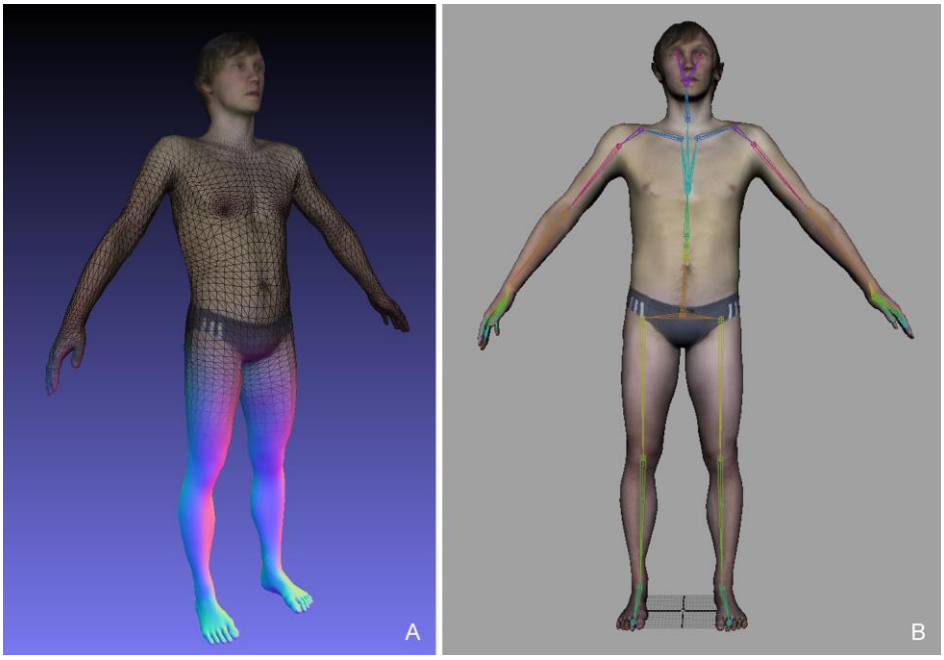

Figure 2: 3D body mesh generated from the body scanner: A) after post-processing, B) with underlying skeleton used to drive animation.

3.2. Motion capture and body animation

The next step is to obtain realistic body animations. For this purpose, motion capture technology is a very practical way that enables to record movements of a real person and to transfer the animation to a virtual body. We used a wireless Xsens motion tracking device [8] consisting of inertial sensors attached to the body by straps. Such systems have the advantage of being portable, allowing tracking in true conditions in the natural environment (i.e., use anywhere, no studio required). Each sensor module contains an accelerometer, a gyroscope and a magnetometer mounted on each bone segment. Motion data are collected by a computer via Bluetooth in an outdoor range of 150 meters. The 3D orientation accuracy is less than 0.5 degrees.

The motions of the athletes were captured during their sport activities. Several trials were recorded to gather all subtleties of the sport movements. The recorded data were post-processed to derive kinematics for each bone segment. A mapping function was used to apply given segment pose information to the virtual body's skeleton. As a result, the skeleton was animated at each instant of time and body deformations were generated using our approach based on dual-quaternion skinning and pose space deformation. Figure 3 shows an animation sequence of an athlete during Nordic skiing.

Figure 3: Animation sequence of an athlete during Nordic skiing. The recorded motion is transferred to the virtual body's skeleton, which generates body deformations.

3.3. 3D garment simulation and motion fitting data acquisition

For the virtual garment simulation, virtual replicas of a selection of real garments were created out of their digital 2D flat patterns. 2D patterns and fabric samples were obtained from the companies Odlo AG and Amer Sports. A state of the art simulation system with high accuracy was used for all simulation experiments [9]. For an accurate virtual recreation and simulation of each garment, fabric samples were measured with a new fabric characterization tool as described in [10] and with a further developed measurement protocol. This new measurement protocol, developed within this research project, takes into account for example a certain type of sport movement and captures the mechanical behavior of a fabric in exactly the same range of stresses and deformations as it happens on the garment during the sport activity. The fabric input parameter and subsequently the virtual garment simulation becomes even more precise.

The recorded motion fitting data (Figure 4) consist of image maps on the 2D pattern and on the 3D garment, where each color nuance corresponds to a numerical value of fabric elongation (orange/red) and compression (blue). Image maps were obtained for the entire motion sequence and for each sport.

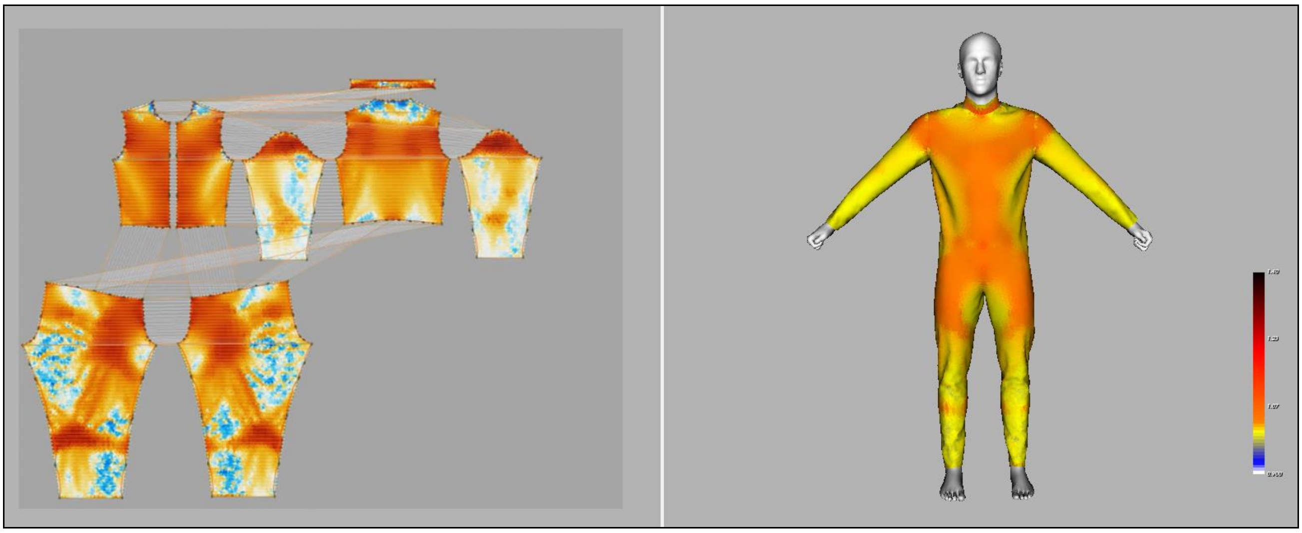

Figure 4: Motion fitting data in 2D shown on the flat pattern (left) and on the 3D cloth (right).

3.4. Evaluation software

In order to easily study the series of image maps for each movement, an image processing tool for an easy data interpretation called FashionViewer was developed. The tool comprises of two main windows, one 2D window to display 2D patterns images and one 3D window to display 3D animations. Time controls allow the user to play and navigate through the animation sequence. Several computations can be performed to analyze the garment deformation during motion:

- *Computation of average garment deformation over motion*: compute the average garment deformation over the entire range of motion, which allows to identify over the animation sequence when the garment deformation is the most extreme.
- *Computation of average polygons deformation over motion*: compute for each polygon of the garment its average deformation over the entire range of motion, which allows to identify the areas of the garment with the greatest compression or elongation over the animation sequence.
- *Computation of area with maximum average elongation or compression over motion*: compute the garment area with the maximum average elongation or compression over the entire range of motion, which allows to identify the area of the garment undergoing the greatest elongation or compression over the animation sequence.
- *Computation of average deformation of selected area over motion*: compute the average deformation of a selected garment area over the entire range of motion, which allows to identify over the animation sequence when this selected area deformation is the most extreme.

4. Generation of new garment aesthetics and functional aspects

For the generation of new garment aesthetics and new functional aspects, fitting maps of each sport were analyzed with the developed FahionViewer software.

4.1. Key postures

The analysis tools as described in Section 3.4 allowed the determination of important key postures for each sport with regards to the elongation of the fabric. It could be identified during which movement the clothing stretched the most or how the clothing behaved at a certain point during a particular movement (Figure 5). A such precise digital analysis of the behavior of clothing on the body in motion is today only possible with the help of virtual simulation tools. For the further development of the 2D patterns, the fitting maps of the key postures where the fabric of the garment is most stretched at a certain point, have been chosen for each sport. The colors nuance of the fitting maps provided the exact fabric elongations of each key postures and served as input for the modifications.

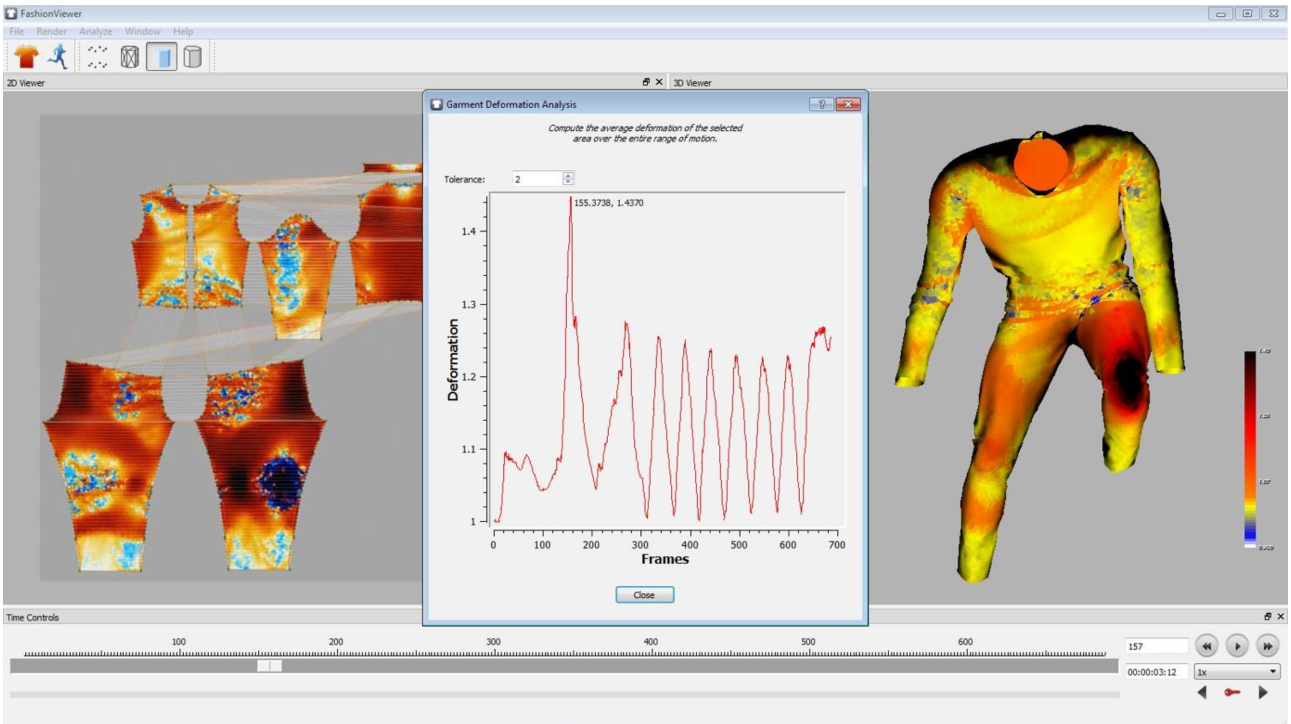

Figure 5: Garment deformations for a mountain bike key posture

4.2. Aesthetic enhancements - dynamic 2D pattern design

The traditional 2D pattern making is mainly characterized by construction points in relation to the static body: hip bones, elbow, knee, shoulder blade, etc. In this project, this method was extended by the body movement. During the simulations, the test garments were stretched along the muscles and over the joints and required additional width at unusual and non-predictable garment zones. An intuitive 2D pattern design was, thus, necessary to “wrap” the moving body (Figure 6). In doing so, each sport required a specific 2D pattern making. The placement of darts, style lines and other means of reducing the fabrics width within the 2D pattern was rather made in a stream (related to an active muscle) than construction-point-based as before and the 2D pattern became finally more dynamic. The fitting maps could additionally be used for a better positioning of the seams, as a seam over a tension area can easily break.

Finally, garments with a more dynamic shape for each sport were developed, away from the “formal” upright body position.

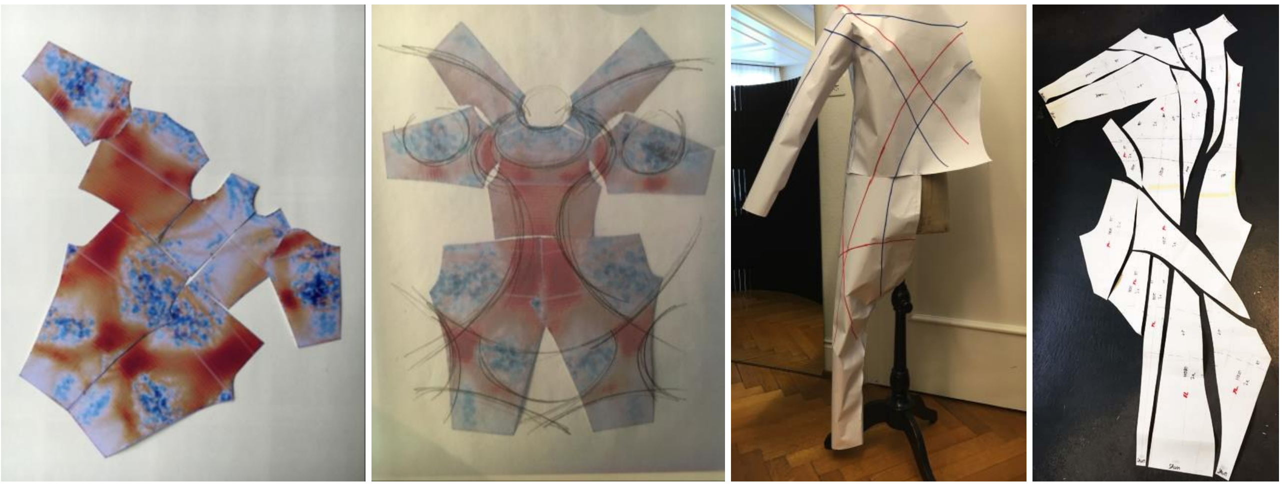

Figure 6: From left to right: motion fitting data, muscle movement, dynamic style lines, dynamic 2D pattern.

4.3. New functional aspects - body mapping concept

The body mapping concept, “a process that scientifically determines where on the body to place different fabrics for the maximum benefit with regards to body physiology and air flow” [11] was applied and extended for this research project. “If sportsmen and women are to be able to concentrate fully on their sporting activity, it is essential that their clothing is comfortable to wear. Making sure they feel nice, dry and comfortable in every situation is the best way of giving their individual performance an extra boost” [12]. However, the clothing should not only be comfortable. With a unique distribution of fabric tensions and deformations during the movement, the garment is not felt any more and the idea of a second skin finally becomes true. Due to the new pattern design, the sports clothing is now completely adapted to the body and its movement. The athlete needs no force anymore for the garment to follow his movement. In high-performance sport this fact can bring the decisive hundredths of a second. In the future the garment could even guide the athlete to find an ideal sports position.

4.4. Clothing physiology aspects

Finally, a sub-project was put in place together with the *Laboratory for Protection and Physiology* of the Swiss Federal Laboratories for Material Science and technology (EMPA) in St. Gallen. The laboratory’s aim “is the development of materials and systems for the protection and optimal performance of the human body with a special focus to analyze the interactions between materials and human skin” with regards comfort [13]. Within this sub-project the air gap thickness and contact area between body and clothing during movement, based on the simulation results of the present project Fashioning Movement, were evaluated.

5. Conclusion

With this research, new avenues are opened up for the development of innovative applications of advanced fashion design, including new flat pattern making. This project demonstrates to the sportswear industry the great potential of integrating the movement into the shape of garments. We will be finally able to develop functional 3D one-piece garments and in doing so create new garments aesthetics. This approach will rapidly influence the sportswear industry and also soon effect the prêt-à-porter fashion industry.

Acknowledgments

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