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3D Product Development Based on Kinematic Human Models

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Abstract

3D product development is a very interesting topic for a widely range of applications on the garment industry. Although the 3D scanning of human bodies is widespread the pattern construction process is done mostly in 2D. One reason is the unusable standard scan posture. Our approach uses scripting to develop a kinematic system inside scan data in a widely automated process. The kinematic system consists of bones and muscles and deforms the surface of the scan data in a nearly realistic manner in any required posture. All modeling and animation work is done in *Autodesk Maya* [1].

Keywords: 3D scanning, automation, character animation, human body simulation, musculoskeletal simulation, 3D product development

1. Introduction

Nowadays virtual human models are used to support the process of product development in the garment industry. With software solutions like *Vidya* by Assyst [2] or Modaris 3D Fit by *Lectra* [3] it is possible to simulate the fit of clothing on 3D models during early development stages. The garment industry is very engaged to work together with the software developers. As a result the manufacturing of prototypes can be reduced. Furthermore the 3D CAD program *Design Concept 3D,* developed by Lectra [3], offers the chance, to generate tight fitting garments in 3D directly on the body surface. In this case the usage of virtual models allows the connection between aesthetical and technical design in the whole development process.

Fig. 1 Garment design in standard scan posture

Figure 1 shows an example for the design of a tight fitting garment developed in the standard scan posture with the mentioned software DesignConcept 3D. This procedure and the flattening process to generate the 2D pattern are state of the art. Work is currently in progress to establish design conditions using 3D models for loose fitting garments [4].

In many applications like sportswear, protective clothing and medical textiles it is necessary to change the posture of the human model to develop the pattern in an application-oriented way. The current virtual models have a static scan posture which cannot be changed. To solve this weakness of the current models developments have been done to make the models moveable by integrating a skeleton structure. However, it has been found that a skeleton is not sufficient to realistically reflect the deformation of the skin surface. Therefore we are going to develop a kinematic human model consisting of skeleton and muscles for pattern construction and simulation.

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2. Methods

The aim of the project is to reflect the anatomic structure of the human body consisting of the skeleton, the muscles and the skin (Fig. 2) as detailed as necessary for this purpose. The kinematic model has the aim to support the apparel industry during the development process and to make the process more transparent. Within the project the skeleton and the muscles will be generated synthetically. The skin will be expressed by individual or standard scan data. The following paragraphs contain detailed information how the different constituents of the kinematic model are generated and assembled. The order is from the inside to the outside.

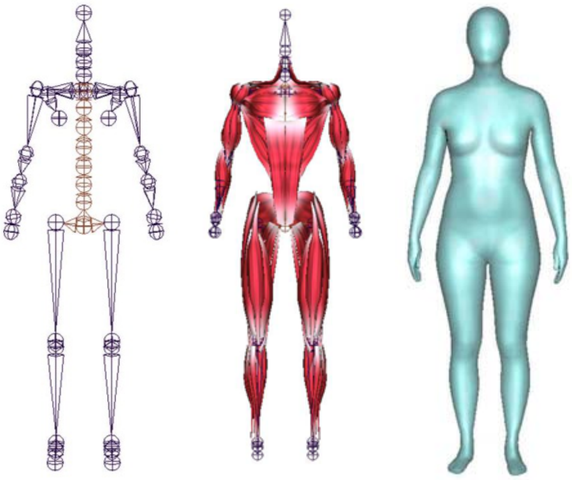

Fig. 2 Parts of the kinematic human model: skeleton, muscles and skin

2.1. Skeleton

With the usage of the software *Autodesk Maya 2012* the structure of the synthetic skeleton is generated. It is important to reduce the number of bones and joints to a necessary minimum for this purpose to ensure the efficiency of the method from the viewpoint of computing effort. As a result the synthetic skeleton consists of 40 joints instead of 206 bones like in the human body. The reduction of the bones is possible because almost half of the human bones are inside the hands and the feeds and are not necessary to generate the postures for the development of garments. The ribs and the jaw bones can also be mentioned in this context.

Gestures like making a fist will not be taken into consideration. The movement of the hand is simulated by one single joint. The natural style of walking is reflected with only three joints in each foot. Those are the ankle, the ball and the toe. Furthermore it is determined that not all vertebras of the spine are necessary to achieve a nearly realistic movability. Because of this only 11 vertebras are used, eight for the torso and two for the neck. More important than the number of vertebras is the natural course of the spine, which is recreated.

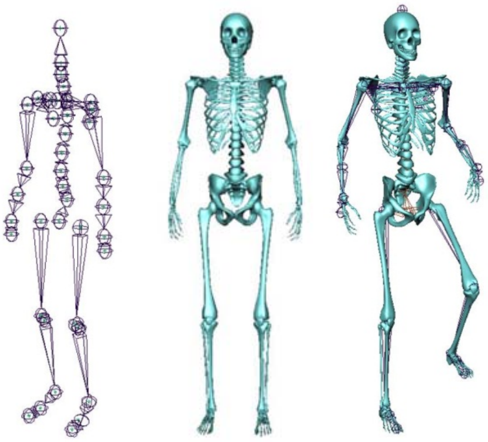

Fig. 3 Synthetic skeleton, polygon skeleton, both

There are also parts of the body where additional bones are needed to generate correct simulations. The forearm has an additional joint to implement the twist between ulna and radius. For the correct movability of the shoulder the collarbone as well as the scapula has been taken into account. This is necessary in order to consider the changes in the posture of elderly people, for example.

It is possible to implement a natural movability of the model by reflecting the anatomic correct constraints of the degree of freedom of the joints (e. g. ball and socket joints or hinge joints). This is done by restricting the individual angles within the joints. The relevant information was taken from literature about anatomy [5].

In order to integrate the skeleton into various scan data locators are placed at the positions of the considered joints. The positions of the locators are detected in two different ways. Firstly an anatomic correct and complete synthetic polygon skeleton is scaled to fit into the scan data. With the help of this the positions of joints, for example for the femur, the pelvis and the vertebras, are identified. Secondly anthropometric features are used, especially for the placement of the locators for the knee, the elbow and the ankle. The joints are generated in a widely automated process by scripting. This process can be done independently for the legs, the arms and the trunk. The anatomic correct and complete skeleton is also integrated to examine the right movement of the joints and the correct placement of the muscles. Small single bones like in the foot or hand are combined according to the used synthetic joints in order not to undermine the above mentioned reduction.

The generated skeleton is used to create an underlying kinematics to obtain movement characteristics and postures. To realize the movement inverse and forward kinematics can be used. In this way it is possible to generate target-oriented movements or to twist single joints into the desired angle. The postures are appropriate for the design of the garments or for the fit simulation to check the wearing comfort of functional clothing, for example. Furthermore the skeleton is used as framework for the scan data. This means that the scan data is deformed by the movement of the skeleton.

2.2. Muscles

Between the skeleton and the scan data representing the skin a layer of muscles is integrated. The muscles are used to deform the skin surface in addition to the joints. Preliminary work for the lower body part has shown that it is necessary to consider the muscles especially in the area of the groin and the knee, which means areas with large movement. From this it follows that the shoulder, the elbow and the waist are important areas for the upper part of the body. But it is not expedient to take all muscles in the human body into account. The reasons for this are as follows: first the movement of the skeleton is joint-driven and second the collision between the muscles is not taken into consideration within this work. That is why the underlying muscles have no influence on the skin. In the course of this superficial layers of the muscles with a significant impact on the skin are given priority [6].

Fig. 4 Muscle structure

The muscle structure (Fig. 4) of the kinematic human model was created with the usage of a *Maya software plug-in MuscleCreator*. With the usage of anatomy literature the muscles have been recreated as exactly as possible [7]. Comparisons with MRI scans, for example, have not been made. After generating the muscles one time and defining their rest, squash and stretch poses and behavior depending on the movement of the skeleton the muscles are integrated in the kinematic model by scripting. As previously mentioned compared to the anatomy the movement of the skeleton influences the movement of the muscles in the simulation. Because of this the origin and insertion locator of each muscle have to be related with the respective joints of the skeleton. The positioning of the origin and the insertion point has to be examined when the leg is moving. During the movement the appearance of the muscles changes slightly, which means that the muscles become shorter and thicker or longer and thinner. In order to keep the computational costs low it is examined which muscles are necessary for a nearly realistic deformation of the skin and which can be neglected. The integration of the muscles into the model by scripting can be executed independent for each part of the body.

2.3. Skin

As aforementioned the skin is represented by scan data. Individual scan data as well as standard scan data can be used. The scan data in the sizes 36, 40, 46 and 50, which we used in the project, were made available by the Hohenstein Institute [8].

To simulate a nearly realistic deformation of the skin an application dependent defined net structure of the scan data is necessary. That is why the disordered polygon structure of the scan data is transformed into a quadrangle net as shown in Fig. 5. This process is connected with quite a lot of interactive work. For reproducible results an automated process is important but this would go beyond the scope of this study. The quadrangle net structure is also essential for the binding process of the skin to the joints within the software *Autodesk Maya*.

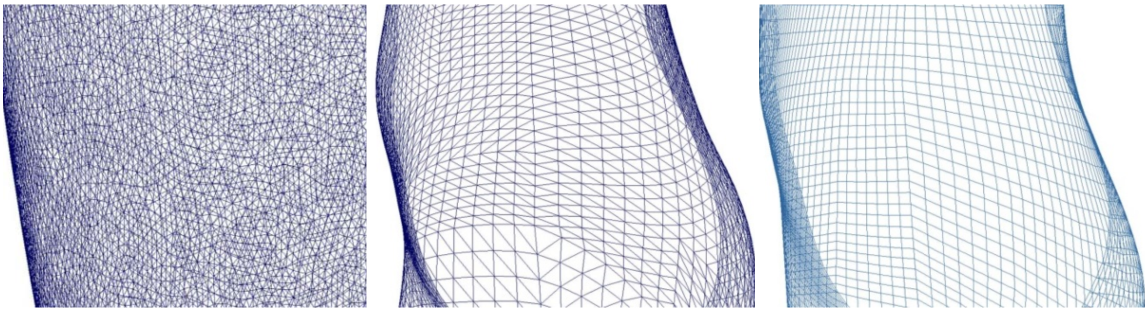

Fig. 5 Optimized net structure of scan data from undefined polygon model to defined quadrangle net

Beside the quadrangle net the course of the edges is also important. Especially in areas with large movement like the groin (Fig. 6) is the course important to achieve an accurate deformation between the thigh and the pelvis.

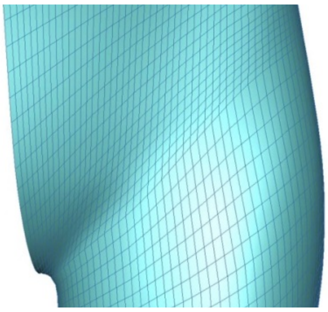

Fig. 6 Net structure in the groin

The easiest way is to place the edges by following the natural curvatures of the human body. It also has been shown that a fine net structure is more suited for the deformation purpose. That leads to higher computational time but they are acceptable because of the much better results of the skin deformation during performance of extreme movements like moving the knee toward the chest. The adaption of the net is done for half of the body and mirrored afterwards.

In order to control the deformation of the surface by the integrated skeleton and the muscles (Fig. 7) it is necessary to define their influences on the surface. That means that the skin is bound to the joints and the muscles are integrated as additional influence objects. Thereby it is necessary to ensure that changes of the shape of the muscles are also taken into account. Otherwise the skin will be unwantedly deformed. The influences of the joints and muscles on the vertices of the mesh, which can be between 0% and 100%, have to be determined interactively one time. The so called skinning has been done with reverse weighting [9].

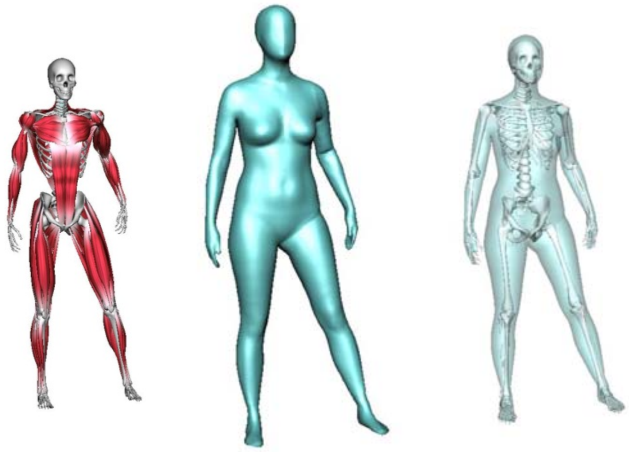

Fig. 7 Scan data with integrated skeleton and muscle structure

After the skinning process is completed the influences can be transferred to other surfaces. The transference process will be executed by the usage of skin weight maps. The result is a nearly realistic deformation of the surface, which has been implemented for the lower body at this time. Figure 8 shows the left leg of standard scan data in the sizes 36 and 40. The whole above described process has been done for size 36. Afterwards the influences have been transferred to size 40. The pictures show different stages of an animation which has been generated with inverse kinematics to examine the right deformation of the surface. Important postures are the upwards pulled thigh, the lower leg angled backwards, the thigh moved backwards and outwards. The movement of the ankle has to be taken into consideration as well.

Fig. 8 Leg, sizes 36 (white) and 40 (blue), in movement

3. Results

The skeleton structure with joints as well as the muscles can be integrated in scan data by scripting satisfactorily. The process is widely automatic. The surface of the scan data is deformed by the underlying skeleton and the integrated muscles in a nearly realistic manner. The transference of the influences of the vertices is sufficient at this stage of progress.

First tests to import the deformed surface in virtual fit simulation software have been successful. Also the integration into design software, for example *Lectra DesignConcept 3D*, has been realized. As an example of usage the trousers for a speed skater have been developed. Therefore the postures of speed skaters have been analyzed as shown in Figure 9. Schenau et al [10] analyzed elite speed skaters and defined the following angles for the typical posture: $\partial 1$= 16.9º, $\partial 2$= 48.7º, $\partial 3$=64.1º and $\partial 0$=112.8º (Fig. 9 left)

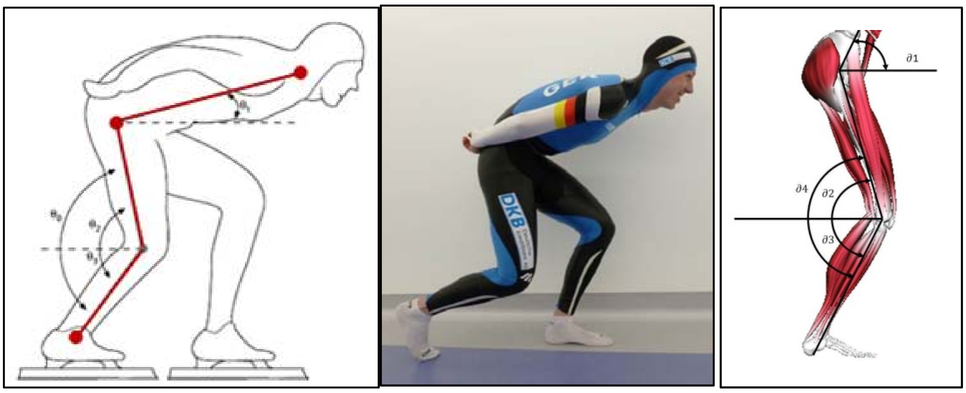

Fig. 9 Speed skater posture

Our own analysis shows the same results (Fig. 9 middle). Furthermore we experienced that the suit must allow enough freedom of movement for the normal walking and standing. Because of this we decided to develop the trouser in a posture between the speed skating and the upright posture with the following angles: ∂1= 60º, ∂2= 75º, ∂3=65º and ∂0=140º (Fig. 9 right).

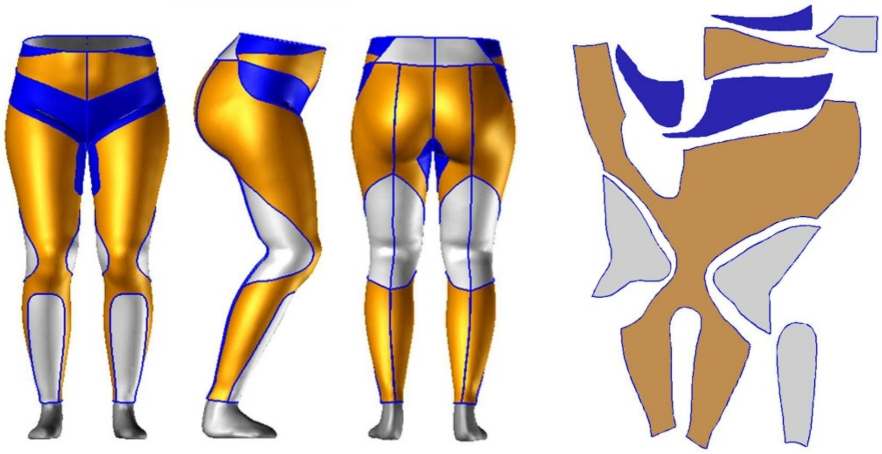

Fig. 10 Speed-skating trouser for size 40 and the resulting patterns

Figures 10 shows the scan data of size 40 in the resulting posture with the design of speed-skating trousers which already takes the necessary patterns into consideration. Because of the posture the designer has the possibility to see the resulting position of seams, for example. During preliminary studies [11] without muscles postures of horseman and rowers have been exported and used to develop the garment design in the posture of usage. The patterns have been compared with those generated from standard scan postures. The results show (Fig. 11) significant differences whose influences on the wearing comfort will be examined in later stages of this study.

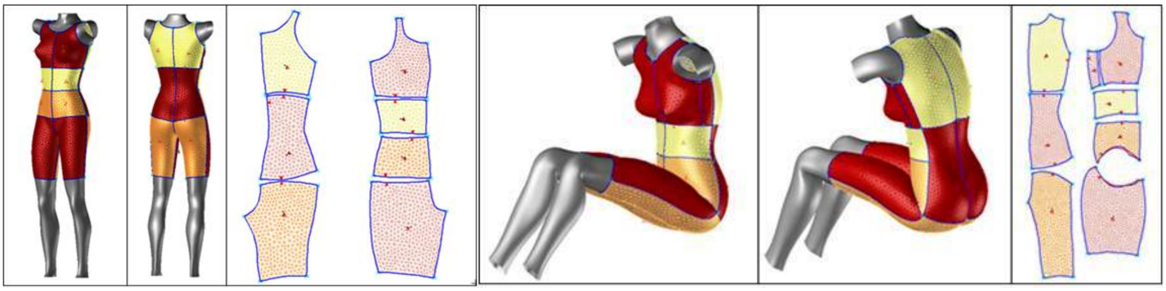

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Fig. 11 Patterns for rowers designed in standard scan posture and posture of usage

As above mentioned the scripts to integrate the skeleton and the muscles into the scan data can be executed independently. This has been considered to give the possibility to work just with parts of the body. For applications like knee bandages is only the leg necessary, for example.

4. Conclusion

With the usage of the kinematic models the user has the possibility to move the joints of the model with exact angles in the required posture. Furthermore it is possible to save and reload motion sequences which are typical for the usage of the clothing. Posture-dependent effects on the pattern construction can be considered. Because of this a better fit comfort can be achieved and the iteration steps can be reduced.

Even with the improvement of the scanners kinematic models will be important because it is much easier and faster to integrate the skeleton into the scan data in the standard scan posture and adjust the posture. That is a good solution particular in the case that the scanned person is not available at any time.

Currently the process of generating the kinematic models is still connected with too much interactive work. To improve this state of the art further developments within the used software solutions are required.

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