

Modeling women's upper body with motion ease for 3D clothing design

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ABSTRACT: To design garments, it is required to have excess amounts for the movement of the wearer's body. Many research projects pay attention to ease, but they are not enough to facilitate 3D clothing design. This study presents a method to create a 3D human body model with corresponding dimensions when moving. This measurement is determined by changing the body's movement posture. This method is performed by 3D scanning the human body in different movement postures using a handheld scanner. Use Rapidform software to model the human body. As a result, the model created is the largest model for the female upper body with measurements corresponding to different movement postures. This model is equivalent to adding a minimum ease for body movement when designing clothes. This research will contribute to improving the method of designing 3D clothes on computers.

Keywords: 3D clothing design, ease, human model

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I. INTRODUCTION

Modeling is a scientific method that aids in observation, data collection, theoretical and experimental research. Research on models is the only way to evaluate technical criteria and choose the optimal structure and parameters... Therefore, many research projects have proposed modeling methods and simulation.

One of the most important characteristics needed for the development of integrated 3D systems in the garment industry is the design of a functional human body model. Nowadays it is possible to model the human body directly from three-dimensional body scan data because the almost body scanner has its advantages, making it easy to choose depending on the research purpose due to advances in non-contact measurement technology.

When designing garment products in general, it is required to have ease for the movement of the wearer's body and ease for fashion to respond to the aesthetics and ideas of the designer. Garment products, when made from non-elastic fabric, require a size larger than the measurement of the human body so that people can move when wearing clothes. Therefore, a minimum movement area to ensure the movement function of the human body inside clothing is always required. The purpose of this study is to create a 3D human body model with an increase in dimensions when moving compared to the standing position. The increase in these dimensions can be determined by changing the body's movement posture. Such a model will ensure that products designed based on this 3D model have the minimum movement area normally required for clothing, thereby contributing to perfecting the 3D design method on computers [1].

Human body characteristics

The human body is a unified mass [2]. The activities of organs in a system as well as the activities of organ systems in the body are rhythmic, ensuring unity.

Anthropometric signs [3] are characteristics of the human body that show changes in structure and rules related to gender, age, occupation, ethnicity, and natural and social factors including dimensions of length, width, circumference, and angular size... Quantitative properties of anthropometric signs are calculated in units of measurement such as centimeters, millimeters, degrees... or by indices and parameter systems.

Movement characteristics of the human body

Human movement changes the distance between points on the body's surface [4]. Researching the movement and range of motion limits of the human body aims to design and manufacture clothes with measurement areas that ensure this movement corresponds to each area of the human body. Human movement is closely related to the skeleton and musculature of the body.

Bones are a strong support for the body and are responsible for protecting important internal organs. The skeletal system combines with the muscles, tendons, ligaments, and nerves to make the body move. Depending on the structural and functional characteristics of the joints at each location, the corresponding level of body

movement will be determined.

Muscles attach to bones, and when the muscles contract, they cause the bones to move. Muscles come in many different shapes and measurements. The muscular system combines with the skeletal system to make the body move rhythmically under the direction of the nervous system.

The joint range of motion (Range of Motion - ROM) [5] is the angle at which a joint can move in different directions. Joint range of motion measured using the Zero method: Standing upright, both palms facing forward, then all joints in the resting position are conventionally 0° , the measurement angle starts from position 0 to the position in which the joint moves, fig.1 and fig.2.

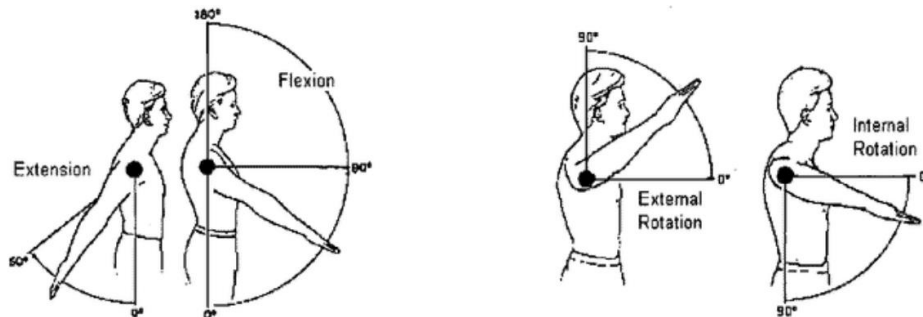


Figure 1. Shoulder joint range of motion [5]

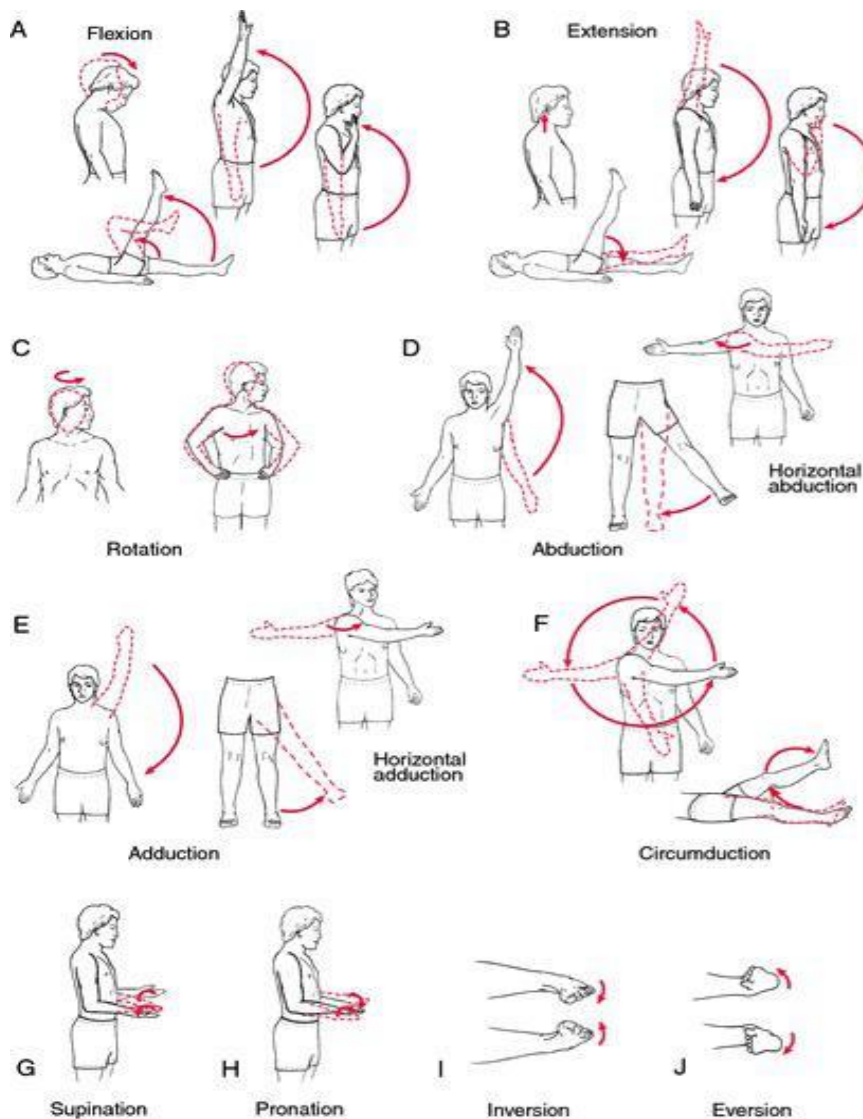


Figure 2. Some joints move [5]

The activities of the human body are very complex and diverse. Most of these activities change the measurement of the human body's surface such as length, circumference, and area. Therefore, the movement of the human body is one of the factors that affect clothing design and is the basis for calculating the minimum design ease, aesthetics and purpose of use, material...

II. RESEARCH METHODS

2.1. Object and scope of the research

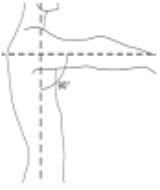
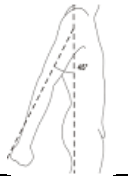


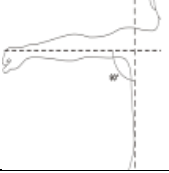
Women aged 18-25 have average size according to TCVN 5781:2009 standards [3].

Research on female upper body measurement with movement postures.

2.2. Research typical movement postures of the human upper body

Determining measurement landmarks and scanning positions is very important, affecting the accuracy and consistency of data obtained between scans. Based on the body's range of motion and scope of research, the research has inherited and presented movement postures with significant changes in body size, table 1.

Table 1. Movement postures of the human body

Scan sample	Movement posture		Resize position
	Posture	Images of postures [6]	
1	Stand Breathe in	The person being measured [3] must stand upright in a natural position so that the three points of the back, hip, and heels lie in a straight line perpendicular to the ground. The head is held straight so that the corners of the eyes and outer ears form a straight line parallel to the ground, and the arms are naturally straight.	Chest Waist Belly
2	Stand Breathe out		
3	Stretch arms out in front. The arm is at an angle of 90° to the vertical axis of the body		Long sleeve Width back Width shoulders Long sides
4	Stretch arms straight back 30°		Rộng ngực Rộng vai Width chest Width shoulders
5	Close and stretch both arms forward 45°		Long sleeves from under the back armpit Width back Width shoulders
6	Close and cross both arms behind 30°		Width chest Long sleeves from under the back armpit
7	Spread arms horizontally 90°		Long sleeves from under the back armpit Sides length from under the back armpit

2.3. Experiment with 3D scanning of the human upper body

Select scanning device

Most current fixed 3D human body scanning devices only allow the person being scanned to stand still in a certain position to measure most parameters of the human body. However, for this study, which is to scan

the body when moving in different postures, fixed 3D scanners are not suitable. Therefore, the study selected a handheld 3D human body scanner with the following characteristics and features:



Figure 3: Handheld 3D scanner Artec EVA & Artec Eva Lite [7]

The Artec Eva scanner is used to create a fast, accurately textured 3D model [7]. Artec Eva is suitable for medium and large-sized objects, a fast scanner with high resolution, and vivid colors. Artec handheld 3D scanner products automatically pair - optimize all scan data. Provides accurate data from 0.1- 0.5mm. Flexible in all rotation angles and space areas. It provides clear images, flexible rotation, easy-to-move tilt angle, and underbody and roof of objects in difficult-to-scan locations. The scanner is of stable quality.

Scanning conditions:

To acquire scanning data, the scanner allows scanning under normal environmental conditions, without requiring special ambient conditions [7].

Object: Female, age 18-25 wearing underwear. Protractors

Tools for locating measuring points: medical tape and, a ballpoint pen to mark measuring points on the tape. 16 landmarks to support and identify during future data processing. These measurement marks are determined according to the standard TCVN 5781: 2009 [3]. Landmarks include the 7th cervical vertebra, cervical throat, 2 shoulder points, 2 shoulder blade points, 2 chest points, 2 waist points, 2 protruding points of the hips, 2 elbow points, and 2 points of hand ankle.

Standing posture positioning tool: straight ruler to limit standard upright standing posture, piece of cardboard to determine foot position when scanning.

Processing scan data

After scanning the human body, the received data is a 3D point cloud of the human body corresponding to predetermined positions. This data is inconsistently located and is not suitable for reproduction or other purposes. Therefore, it is necessary to put this data in the correct location. To process scan data, the research was performed on Rapidform XOR3 software.

Select the origin and realign the coordinate axes for 3D images. In this experimental part, the research selected the coordinate origin as the 7th cervical vertebra point for 3D data corresponding to the scanned body positions.

2.4. Model of the human upper body

Reconstruct a 3D model of the human body

The research recreated a 3D model of the human body on Rapidform software combined with TCVN 5781:2009 standards. The steps are as follows:

Based on typical anthropometric points, determine the distance from the 7th cervical vertebra to the waist. Divide this distance into 27 equal intervals [8] to obtain the positions of 28 cross-sections from the 7th cervical vertebra to the waist. Take 17 more cross-sections from the waist to the hip to serve as an upper body model - figure 2.2. The distance between 2 cross-sections from the waist to the hip is equal to the distance between 2 cross-sections from the 7th cervical vertebra to the waist. Number the planes from 1 to 45 from the 7th cervical vertebra to the hips, fig.4.

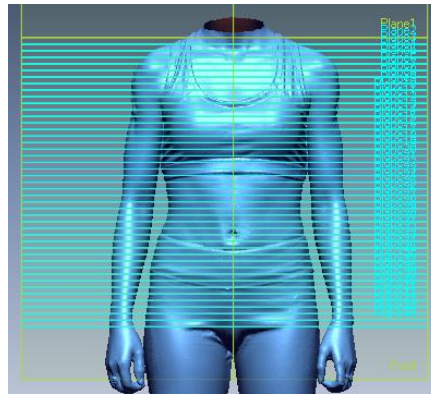


Figure 4. 45 cross-sections of the human body

Take the border of the body at each cross-section for each movement position of the body when scanning, inheriting research [8] on the topic of taking each cross-section with 72 equally spaced points. Extract the dimensions for each border. Since the human body is considered symmetrical on the right and left sides, half the border should be taken for each cross-section. Each curved surface is created through these two borders that will connect the curved surfaces into a smooth half-surface of the human body model. Then, the symmetry half the body model to form a complete upper body model.

Create a 3D model of the human body that changes in size when moving compared to a standing posture





To create a 3D model of the human body when moving with changing dimensions compared to the stationary position, the research compared the body border at each cross-section corresponding to different movement positions to get the edge. The form has the greatest change in size compared to the standing position. Gather the border at the body locations with the greatest change in size to create the largest upper body model from the determined moving body positions.



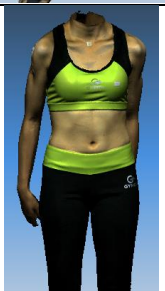
III. RESULTS AND DISCUSSION

3.1. Typical movement postures of the human upper body

3D scanning results of the human upper body with movement postures

Table 2. Results of 3D scanning of the human upper body

Scan sample	Scanning posture	3D scanning results	Scan sample	Scanning posture	3D scanning results
1	Stand Breathe in		5	Close and stretch both arms forward 45°	
2	Stand Breathe out		6	Close and cross both arms behind 30°	

3	Stretch arms out in front. The arm is at an angle of 90° to the vertical axis of the body		7	Spread arms horizontally 90°	
4	Stretch arms straight back 30°				

3.2. Results of the 3D model of the human upper body

Scan data processing results

3D images received from the scanner need to be processed to remove redundant data, supplement, fill in missing areas, and increase or decrease data to make the image sharp but must ensure that the data is enough to work quickly in the next steps and avoid the data being too large.

The 3D image received from the scanner is not in the standard position, it is necessary to align the coordinate origin, front, back, and top and bottom of the image to unify the models together.

Process the data and select the coordinate origin as the 7th cervical vertebra point for the scan samples and Fig. 5.

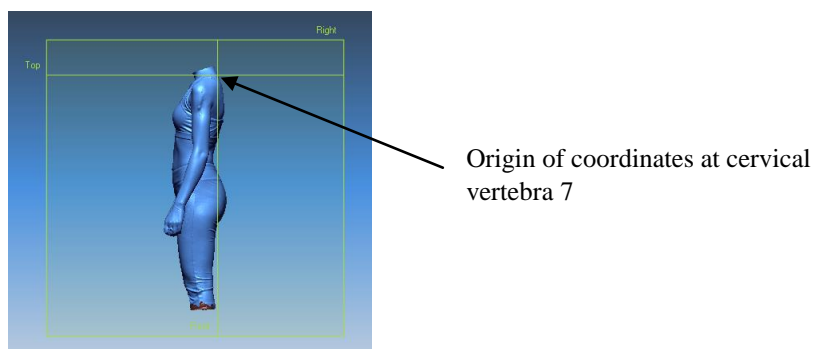


Figure 5. The image is aligned and the origin coordinates of the scanned samples

Results of upper body model reconstruction

Data processing and human body model reconstruction are performed on Rapidform XOR3 software. The steps are as follows:

Set up reference planes at the cross-section positions

- Determine the distance from the 7th cervical vertebra to the waist
- Divide the distance from the 7th cervical vertebra to the waist into 27 equal segments
- Set up reference planes at the newly divided points
- Take 17 more cross-sections from the waist to the buttocks with the same distance to serve the reconstruction of the upper body model - figure 2.2

Take half the border of each cross-section

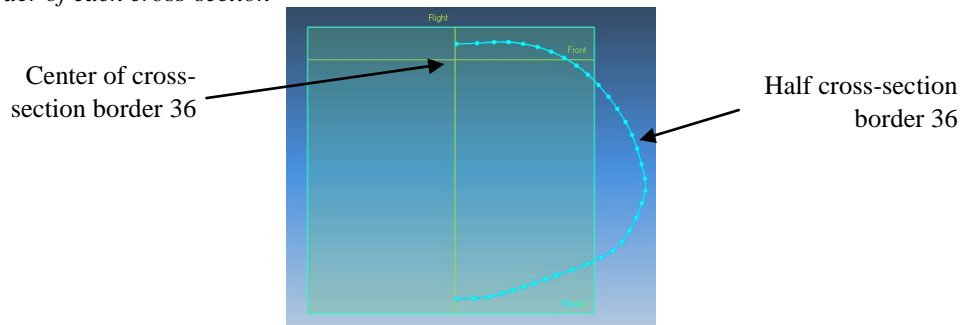


Figure 6: Half border of cross-section 36 of sample 1

Set of half-borders of cross-sections, figure 7a.

Create half the surface of the body model, figure 7b.

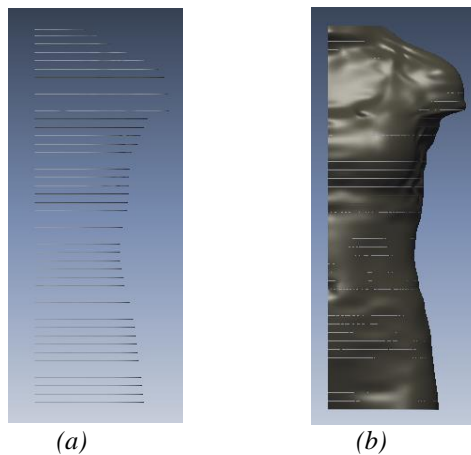


Figure 7. Half-body model of model sample 1

Use symmetry to construct a model of the upper body, figure 8.

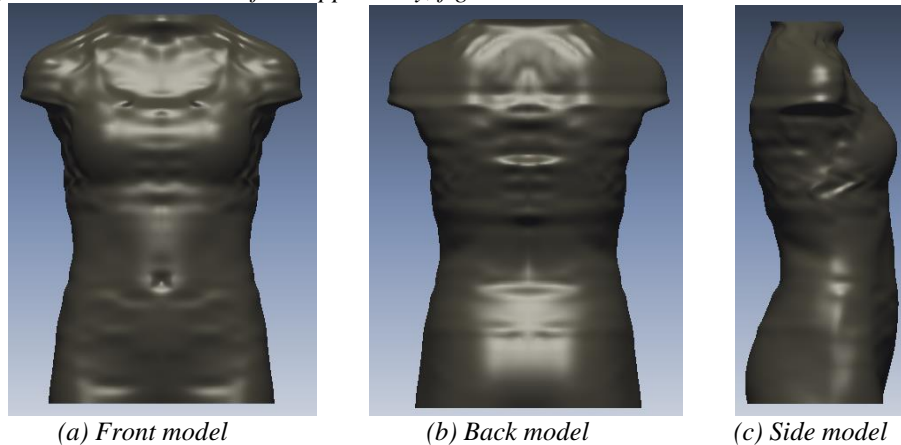


Figure 8: Upper body model of sample 1 (when standing)

3.3. The resulting 3D model of the human body when in motion changes in size compared to the standing posture

3.3.1. Extract parameters from cross-sections of scanned samples

Parameters of each cross-section are extracted: Cross-section border length (mm), cross-section center coordinates, and cross-section size in 3D space: width, height, depth (mm). Scan sample numbers are as shown in table 3, plane numbers are from 1 to 45 (from the 7th cervical vertebra to the hip).

Table 3: Parameters of cross-sections at plane 36 of the scanned samples

Scan sample	Cross-section	Half-length of cross-section border (mm)	Center coordinates (x, y, z)	½ Cross-section size (width, height, depth)
1	36	388.0291	-3.1928, -416.15, 83.0734	145.6811, 0, 192.8273
2	36	390.18465	-3.1131, -416.15, 87.2177	145.8409, 0, 195.2929
3	36	393.5361	-3.1334, -416.15, 106.9555	146.2616, 0, 194.6298
4	36	381.32515	-1.3401, -416.15, 68.3252	145.1928, 0, 185.7396
5	36	395.11385	-1.8573, -416.15, 102.8297	146.9636, 0, 196.4425
6	36	378.59095	-0.2645, -416.15, 68.3087	144.1739, 0, 183.423
7	36	390.1267	-1.7878, -416.15, 85.5371	146.728, 0, 191.5183

3.3.2. Compare the cross-section-by-cross-section borders of the scanned samples

Compare the cross-section-by-cross-section borders of the scanned samples and retrieve the border with the largest change in size compared to the standing posture among the scanned positions. For the 36th cross-section, looking at chart 1, the half border of sample 5 is the largest.

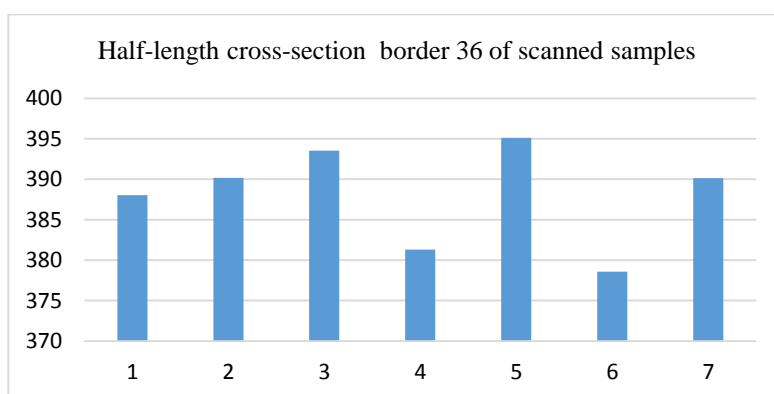


Figure 9: Cross-section 36 border length of scanned samples

3.3.3. Moving the center of the largest cross-section border

Moving the center of the largest cross-section border to coincide with the center of the same cross-section on sample 1 to get the pose of the model being created as the natural pose of the person being scanned.

Select model 1 whose body position is scanned according to TCVN as the standard posture.

The coordinate of the center (x, y, z) of each cross-section, table 3 showed that:

- The border of each cross-section (right and left) is symmetrical about the x-axis so there is no need to adjust the position of the center along the x-axis
- The border of each cross-section is equidistant from the origin of the coordinate for all cross-sections, so there is no need to adjust the position of the center along the y-axis
- The border of some cross-sections moves along the z-axis due to changes in body posture, so it is necessary to move the position of the cross-section center to coincide with the center of the corresponding cross-section on sample 1.

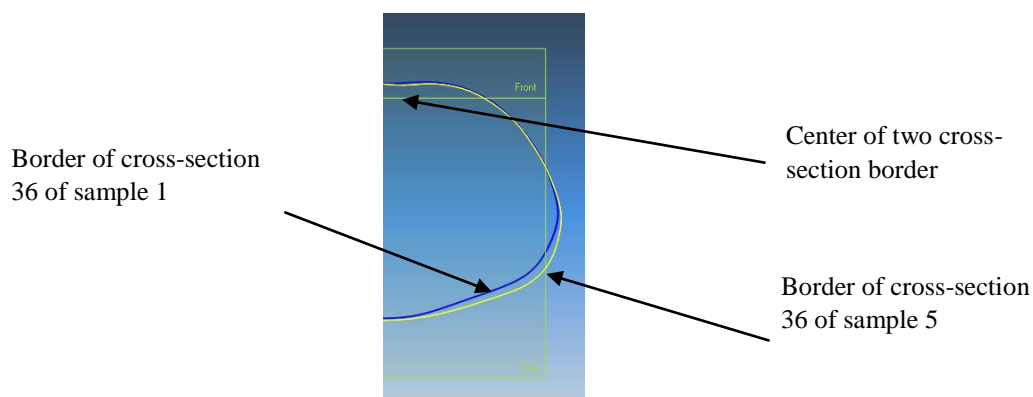


Figure 10: Move the center of cross-section border 36 on sample 5 to coincide with sample 1.

*** Do the same for the other cross-sections for the scan samples to get the largest set of borders.

3.3.4. Create a curved surface

Create a curved surface that passes through two borders, then connect the curved surfaces into a smooth half surface of a human body model with boundary conditions.

Take the symmetrical halves of the model and combine them to form a human body model, fig.11.

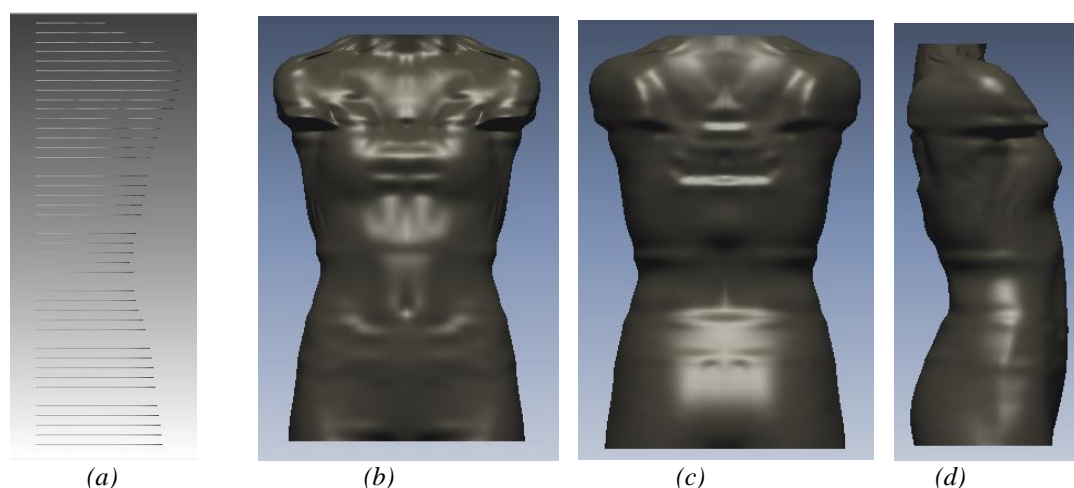


Figure 11: 3D model of the human body when moving, the size changes compared to the standing posture.
 (a) Extraction of maximum border index of cross-sections taken from scanning samples
 (b) Frontal model
 (c) Rear model
 (d) Side model

IV. CONCLUSION

1. The research performed 3D scanning of the human body with different body movement positions using an Artec Eva handheld scanner, while other fixed scanners can only scan the human body in a certain standing position. Different body movements are performed based on TCVN 5781: 2009 standards to ensure consistency between measurement samples and facilitate data processing in the next steps.

2. The research has proposed a method to construct a model of the human upper body corresponding to each movement posture and has extracted the borders and parameters of female upper body cross-sections in different movement postures, thereby determining the largest border of each cross-section for the scanned samples. Based on the largest border of each cross-section, the research has created the largest model for the female upper body corresponding to different movement postures. This largest model is equivalent to adding a minimum allowance for movement when designing clothes.

3. The largest border of each cross-section is moved to the position corresponding to the same cross-section number of the standard pose, so this largest model ensures the standard pose for the garment design. Using the largest human body model to design clothes in 3D will help designers more conveniently, have a more intuitive view of the product to be made while still ensuring movement for the wearer. Using this model to try

on virtual clothes will help consumers make more accurate decisions to buy products online to avoid returning them later.

The research has created the largest model for the female upper body corresponding to different movement postures for the horizontal dimensions of the body. In the next research, we will mention the dimensions according to the length of the upper body and continue to work on other parts of the body to contribute to perfecting the 3D clothing design method.

REFERENCES

- [1]. Đỗ Thị Thùy, 2020, *Các phương pháp thiết kế mẫu quần áo ba chiều trên máy tính*, Tạp chí Khoa học và Công nghệ, Tập 56, Số 6 (12/2020), <https://tapchikhcn.hau.edu.vn>
- [2]. *Atlas Nhân trắc học người Việt Nam trong lứa tuổi lao động*, 1986- NXB Khoa học và Kỹ thuật Hà Nội.
- [3]. TCVN 5781:2009, Ban kỹ thuật Tiêu chuẩn quốc gia TCVN/TC 38 Vật liệu dệt, Tổng cục Tiêu chuẩn Đo lường Chất lượng, Bộ Khoa học và Công nghệ.
- [4]. Atlas Giải phẫu người
- [5]. <https://i.pinimg.com/originals/fb/b1/8e/fbb18ec99db5a5604992d40d00083155.jpg>
- [6]. Triệu Thị Mai Yên, 2014, *Nghiên cứu sự thay đổi kích thước phần thân trên cơ thể trẻ em nam lứa tuổi tiểu học ở trạng thái động làm cơ sở xác định lượng gia giảm thiết kế tối thiểu của quần áo*, luận văn thạc sĩ, trường đại học Bách Khoa Hà Nội
- [7]. <http://scantechvn.com/may-quet-3d-cam-tay-artec-eva-artec-eva-lite-sctvn352>
- [8]. J. Fan, W. Yu and L. Hunter, 2004, *Clothing appearance and fit*, published by Woodhead Publishing Limited in association with The Textile Institute Woodhead Publishing Limited Abington Hall, Abington Cambridge CB1 6AH England.