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DEVELOPMENT OF CLIMBING CLOTHES USING COMPUTERIZED 3D CLOTHING SIMULATION

The purpose. *This paper aims to explore the applicability of computerized 3D virtual clothing simulation programs for the development of patterns for men's rock climbing pants.*

Methodology. *The experiment involved comparative methods of virtual wearing, as well as pressure points, perspective map and appearance evaluations. The theoretical and methodological basis of the research are scientific works presenting data from 3D virtual fitting software.*

Results. *The study selected three designs of climbing pants to compare the layout of patterns and to analyze the appearance through virtual garment fit maps. First, the 2D-to-3D was applied to develop garment patterns of a rock climber's pants. The patterns were developed directly in the 3D software. The flat patterns can be visualized in the sewing/assembly stage of the prototype. Then, 3D animation technology was used in simulation. The results throughout the study were: 1) 3D simulation of three different types of pants design. 2) Evaluating the fit and comfort of the clothing using garment fitting maps. 3) Identifying the most discomforting parts of the patterns, thigh, hip, waist, pants hem and knee girth. 4) Modify and adjust the clothing according to the evaluation situation.*

Scientific novelty *consists in providing a systematic methodology of utilizing 3D simulation for a specific category of wearers, such as rock climbers.*

Practical significance. *The considered research directions of 3D clothing simulation can be used by designers and patternmakers in the creative and experimental process of designing clothes expanding the possibilities of software to transform functional design in the industry and research.*

Key words: *climbing; pants pattern; virtual fitting; design; 3D simulation; prototype.*

Introduction. With pandemic restrictions making it difficult to work directly with models, virtual fashion shows have become more prominent worldwide. A number of 3D virtual programs are available on the market, such as Clo 3D, Lectra, Optitex, V-stitcher, TUKA 3D, etc. The programs are showing virtual garments in static and dynamic poses on a 3D mannequin, with the possibility to choose fabric properties (texture, draping, elasticity, etc.) and sew the patterns by fabric technical parameters.

Based on the growing number of bouldering participants, in the present study we used a garment system that makes clothes patterns and 3D virtual fitting experiments for this specific category. Rock climbing is unique from a physiological point of view because it is a physical activity performed against gravity, a combination of body movements created with kinematic and kinetic parameters which require sustained muscle contractions for upward propulsion. Designing mountaineering, single-pitch, bouldering or gym climbing pants for this specific category of athletes assumes the understanding of rock a climbers body, equilibrium techniques and moves, environmental conditions, and using ergonomic design principles to minimize discomfort and improve performance.

Taking into consideration the latest advancements and adaptation of the clothing industry, we will present the theoretical background and review literature regarding the applications of 3D virtual simulation. Information on anthropometric data is a precondition of garment patterns design [1]. In static anthropometry, people are measured in unmoving, defined postures. Functional anthropometry includes dynamic reaches and strength measurement with the body engaged in various postures. Dynamic anthropometry is a major research topic in clothing technology.

Analysis of previous researches. In 3D garment design, the mannequin is basically a personalized 3D human model from measurement of a body with anthropometric equipment, 3D body scanner or a measuring tape related to a specific client [2]. The researchers stated that the key to the functional design of clothes with special destination is simulation of its protective functions during its activity [3]. Lee compared in 3D virtual fitting two methods of pattern development to determine curved design lines and their three-dimensional construction, the offset and the split grading type. He analyzed the inguinal region and back crotch area in virtual fitting of two outdoor pants patterns. The difference between the 3D offset/projection and the split grading method was at the location where several curved lines merged [5]. Liu W. measured the pressure of yoga suit under different wearing states through the virtual clothing pressure tool of the CLO 3D platform [11]. For example, Jeong Y. & Hong, K. [3] measured and analyzed the pressure points in a static state and a cycling dynamic state with 3D human scan data. Then, based on the change rule of pressure, a clothing pattern optimization scheme was proposed and optimized the design of cycling jersey patterns. K. Liu et al. [4] built a pants fit evaluation system based on the CLO 3D platform and came to the conclusion that clothing pressure data from 3D virtual fitting software has predictive accuracy on the assessment of garment fitness.

Statement of the problem. Rock climbers need clothes that fit well, are comfortable and do not restrict the climbing body movements. Therefore, dynamic anthropometry is crucial for sportswear and personal protective cloth design. The fit of designed prototype in static and dynamic body posture through virtual fitting was analysed. A comparison was performed involving the clothing stress, strain, fit map and pressure points using CLO 3D, a design software with an intuitive interface and 3D simulation suitable method, to come to a definitive conclusion and get a good visualization of the products design. Therefore, the purpose of this study is to develop bouldering pants patterns and evaluate their static and dynamic wear comfort in 3D virtual try-on experiment. The process of clothing simulation is illustrated in the diagram below (Figure1).

Fig. 1. Virtual garment fitting process diagram

Results of the research. CLO 3D system version 6.0 was used as experiment platform in order to identify the fit analysis capability promoted through virtual prototypes. 3D clothing software has been developed for modeling the body and the garment in virtual environments and includes three basic modules: 1) a mannequin module to model a human body, which is built using measurements from a real body; 2) a fabric module to simulate fabric properties; and 3) a pattern sewing module to virtually sew segments of 2D patterns together to generate a 3D garment mesh.

These modules permit the complete computerized 3D clothing simulation of the process of real garment making. In this study, CLO 3D (http://www.clo3d.com) was used to implement the virtual garment try-on. This system has been validated as having an accuracy rate of up to 95% based on measurements of the stretch, bending, and other physical properties [8, 10]. Real fabrics used in the fashion industry can be converted into virtual fabrics. Motion data can be imported to simulate human movement and create animation. The CLO program was utilized for 3D simulation method on the parametric avatar, in order to reduce time and costs needed to make the garments.

The first step in designing virtual clothing is to choose a mannequin as the basis form. For this study, the body of a male subject was directly measured according to ISO 7250-1:2017, in terms of body measurement items like height, bust circumference, natural waist circumference, waist circumference, hip circumference, upper thigh circumference, lower thigh circumference, knee circumference, calf circumference, ankle circumference, crotch height, knee height. Table 1 presents body measurements of the male subject to be generated as a 3D virtual male model avatar within the 3D clothing software.

The male avatar is presented in two kinds of display effects: dynamic and static. The dynamic display is the effect when the model is exercising and this is equivalent to the effect of people walking normally. It is generally convenient to observe the overall effect of the clothing. The dynamic display of the general effect is still in the model, adding to its specific movements and gestures it can be dynamically displayed. Therefore, before designing a garment in 3D, the design of the mannequin is particularly important, the anthropometry, shape and posture of the models play a very important role, as shown in Fig. 3 [1].

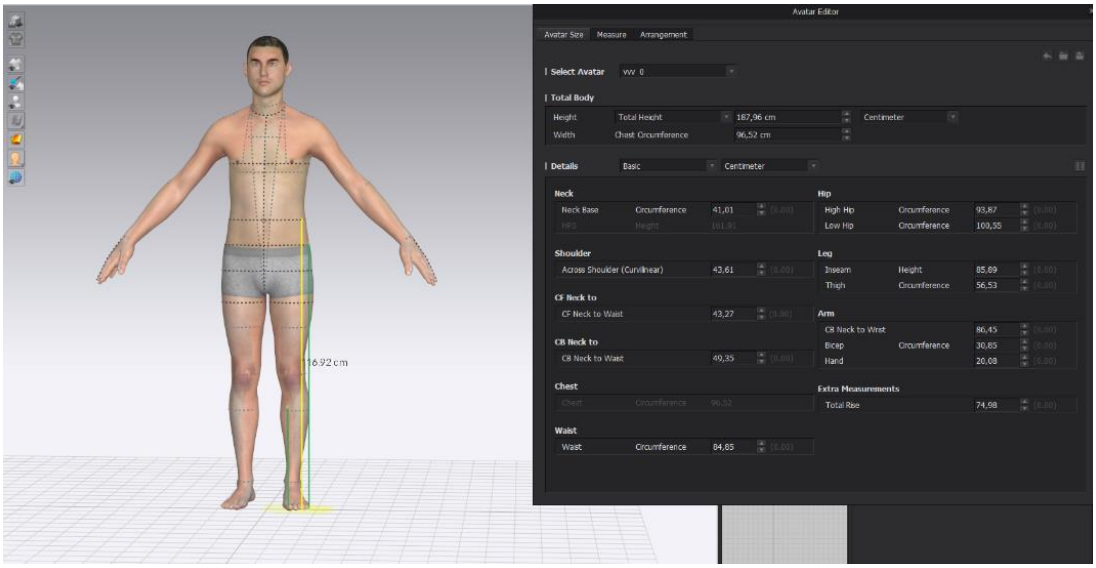

Fig. 2. Mannequin characteristics

Table 1. Body measurements of the virtual male model

Abbreviation	Body measurement items	Body measurements (cm)
BH	Body height	181
BC	Bust circumference	96
NWC	Natural waist circumference	74
HC	Hips circumference	94
UPC	Upper thigh circumference	55
LTC	Lower thigh circumference	50
KC	Knee circumference	35
CC	Calf circumference	36
AC	Ankle circumference	22
CH	Crotch height	87
KH	Knee height	53

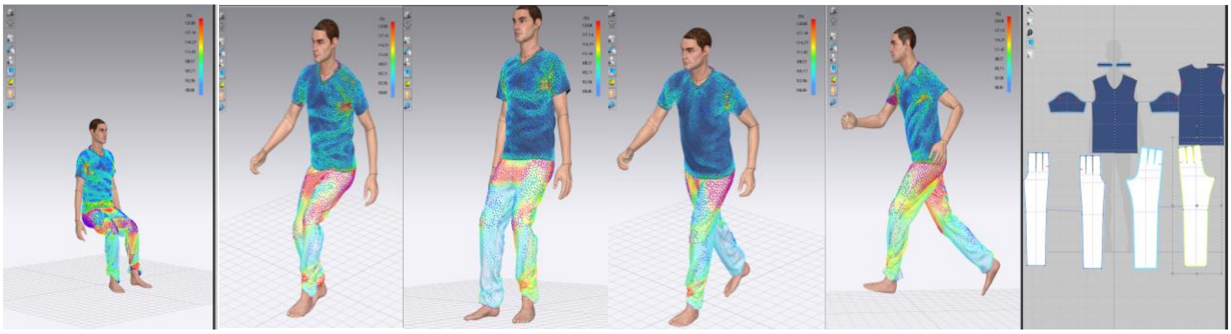

Fig. 3. Mannequin poses

The first step to design 3D garments is to create a 2D version of the model. This part also can use CAD import directly: after the 2D plate suture, the 3D layout automatically synchronizes with the 2D layout; then click the arrange point on the 3D page. This step is very important. As shown in Fig. 4, we have to make sure that these points are positioned in the right place and are as close as possible to the avatr, in order to avoid any disorder during fitting. In the process of sewing, the suture tool should be selected to stitch from the top to the bottom and then from the inside to the outside. Then, the 3D interface will be stitched in synchron. In the simulation process, the clothes will be worn on the human model according to the previous arrangement and design of patterns.

After the completion of sewing and place of patterns arrangement, the fabric attributes need to be selected. In the end, we can finally check the garment and also adjust or modify some relevant characteristics, such as color, brightness, tightness, fabric direction, density, etc. We did these virtual garment process for the three designs (Fig. 5).

Before using Garment Fitting Maps we prepared the avatar in the right size and we chose the avatar s pose. For the virtual samples we chose the same type of fabric. It is important to use identical or in case, similar fabric that will be used on the real garment, in order to achieve an accurate virtual fitting.

The distribution chart of contact pressure points can reflect the stress level of the clothes [7]. We can distinguish according to the color of the display. If the cloth is being stretched really hard, it is shown in red, and for the opposite it is shown in the green color. However, if the area of green is bigger, the clothes have less pressure on the human body. Contact point is used to observe closely the extent of contact between the human body and the garment [11]. Through the distribution of the pressure of the clothing, it can be very intuitive to see the pressure of the virtual model when wearing the clothing. We measured the pressure of rock climber's trousers under different wearing states through the virtual clothing pressure tool of CLO 3D platform (Fig. 7).

The fit map is evaluated for whether the virtual model is suitable for wearing these pants. This is shown in Fig. 8, it can be seen that the clothing on the avatar is divided only into two colors. Each fabric has a maximum distortion and the value is determined by stretch, shear and stiffness in the physical properties of the fabric. Yellow stands for a specific position that feels tight, and the proportion of the total clothing; Red represents the area where it can't be worn and the proportion of the overall clothing. In the yellow area, you can adjust according to the effect achieved by the clothes. However, the red part must be adjusted, otherwise the red part of the actual clothing cannot be worn normally. We must say that the discomfort parts are on the waist and hips circumference The Fit Map is calculated for the areas in which fabric and avatar are in contact and shows how many sections of the garment have reached.

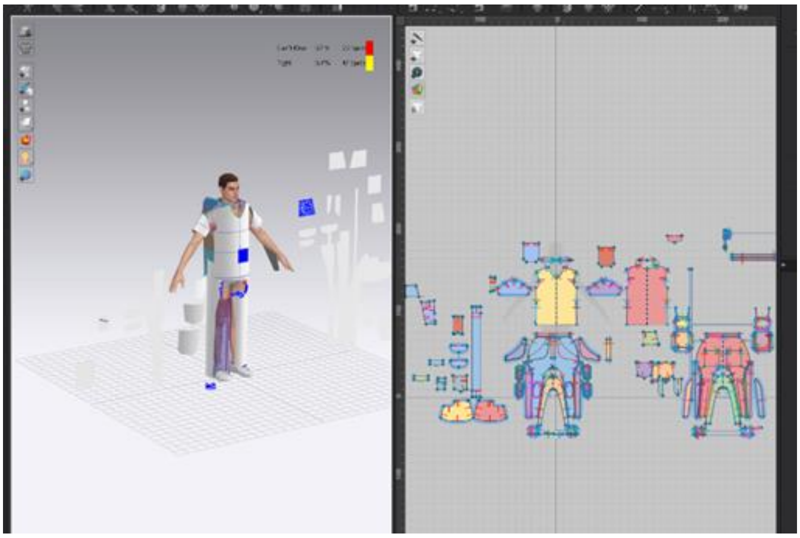

Fig. 4. Rock climber's pants pattern panels arranged around a virtual mannequin with the creation of segment sewing

Fig. 5. Rock climber's pants designs (a) Tight-fit pants; (b) good-fit pants; (c) loose-fit pants

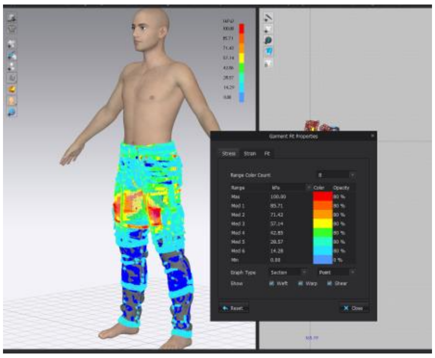

Fig. 6. Exemple of workflow (b) good-fit pants

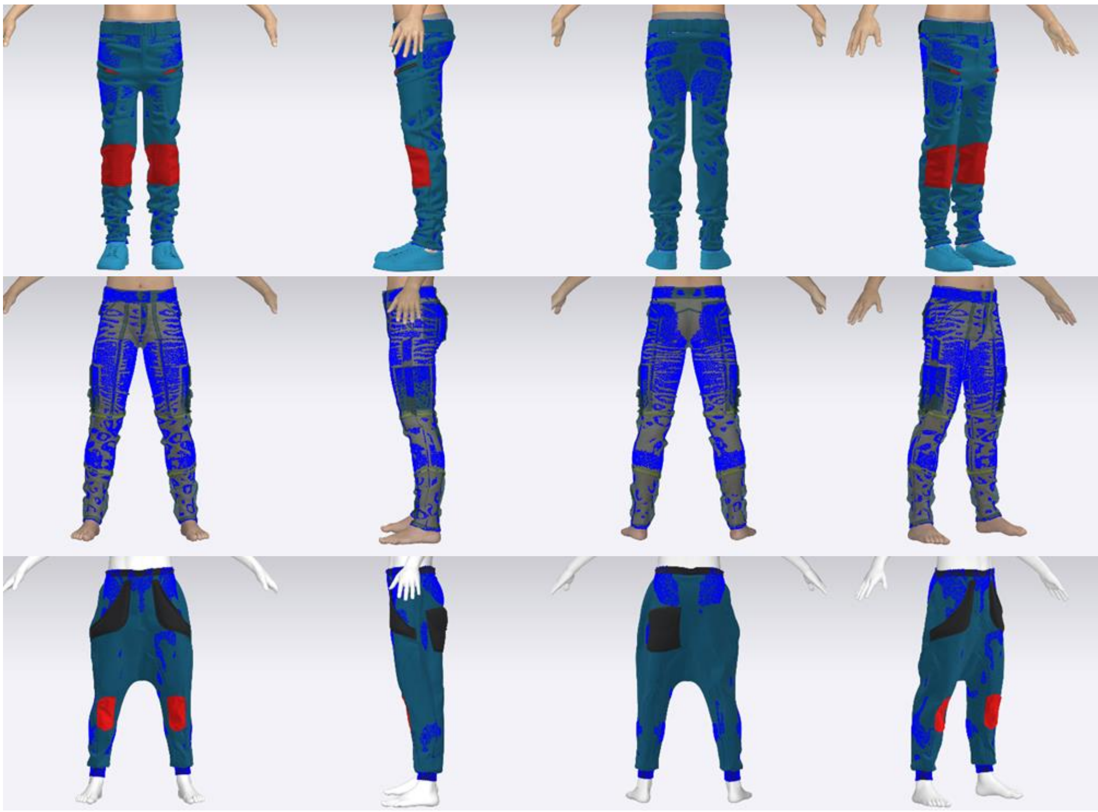

Fig. 7. Pressure points tool for fit pants

Fig. 8. Fit map

Fig. 9. Strain map

Fig. 10. Stress map

The Strain Map represents the rate of distortion of clothing due to external stress and is quantified in percentage form and is represented by a color diagram. Red indicates 120% of the distortion rate while blue indicates 100% (no distortion).

This is shown in Fig. 9. and the map indicates the degree of tension caused by the pressure itself. Through the strain map, it can be seen how much the deformation of the garment fabric occurs after being worn on the virtual model. If the area shown by the fabric is red, the fabric is stretched more than 120%. At this time, corresponding to the previous introduction, clothing pressure on the human body has more than the human body can bear. In the fit map, it is shown as unwearable; the orange to yellow area indicates that the stretch of the fabric is between 110% and 120%. This means that although the human body has a sense of urgency when wearing it, it is usable. For some tight-fitting clothes, it can be within this tolerance; Green indicates that the fabric is in normal condition. The Strain Map shows how much the garment is stretched when being worn.

To get more accurate results we raised the percentage value for the stretchy fabric. In the Strain Map the Blue shows areas where fabric is not stretched, while red shows the most stretched parts. That doesn't mean that the red areas are a critical issue. The next step is to consider those zones part of the protocol that have to be investigated by using the Stress Map.

The Stress Map shows the external stress causing garment distortion per area of the fabric, and appears in the range of colour and numbers. Stress Map red colour indicates the strongest stress (100kPa) while the blue colour indicates zero distortion (0.00kPa). we can see how much pressure is in the fabric per section resulting from a tight-fitting garment.

We observed that were the trousers pattern shows blue or green in the Strain Map [%] and then a high value such as red or orange in the Stress Map [kpa], our climber would be uncomfortable wearing a low stretch fabric. If we chose a stretchy fabric for the pants, we will obtain a red/orange garment with a high value in the Strain Map, but low pressure value in the Stress Map. We can interpret that the sport item should be tight, but with the characteristics of the fabric it will be stretch enough so the climber is not subjected to uncomfortable pressure inside the garment.

From the observation of the simulation patterns, it was possible to identify some aspects to be improved: small fabric parameters to be adjusted. The evaluation from the fit perspective was based on the analysis of images such as tension graphs with the test body in a sport setting, in static and dynamic positions. It was possible to observe the clothing's behavior and the tension generated in a simulation of use. Based on the principle of minimum average pressure, the pattern of trousers was optimized to improve the pressure comfort.

Conclusions. The results showed that the pants can be optimized and the pressure comfort can be improved by analyzing the pressure points, stress, strain and fit maps, but depends on the chocee of fabric. The Clo 3D software allows patternmakers to use their own expertise and know-how to parameterize anthropometric data and to get renderings from 2D patterns in a short time. This is a software that fashion designers use to complete garment design and production. It can completely meet a series of design requirements that fashion designers might have, such as fashion design, pattern making, adjustment and modification, fabric selection, visualization and marketing. The strain map and the pressure map show data very similar to possible intuitive considerations. The difference between the two is that the pressure map reflects the pressure of the garment on the virtual model, and the strain map indicates the degree of tension caused by the pressure itself. In the experiments, an avatar was first modeled based on anthropometric values. Three pairs of straight pants including good-fit, loose-fit, and tight-fit were designed in order to better visualize how the clothing items would fit and perform in different stress scenarios. The emergence of accurate 3D software for garments has had a significant impact on the fashion industry in the last years. The advantages of 3D design software in augmenting the garment design process are clear, allowing the designer to see their concept in real-time and do preliminary testing in order to define materials, pattern use, etc.

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РОЗРОБКА ОДЯГУ ДЛЯ СКЕЛЕЛАЗІВ ЗА ДОПОМОГОЮ ПРОГРАМ 3D-МОДЕЛЮВАННЯ

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Мета – дослідити придатність комп'ютеризованих програм віртуального моделювання одягу для розробки моделей чоловічих штанів для скелелазання.

Методологія. Експеримент включав порівняльні методи віртуального одягання, а також визначення точок тиску, перспективну карту та оцінки зовнішнього вигляду. Теоретичною та методологічною основою дослідження є наукові роботи, що представляють дані із програмного забезпечення для віртуального 3D-проектування одягу.

Результати. В роботі виконано порівняння розміщення деталей та аналізу зовнішнього вигляду трьох конструкцій штанів для альпіністів за допомогою візуалізації моделей на тривимірному манекені у програмі CLO 3D. Технологію 2D-to-3D було застосовано для розробки моделей одягу штанів альпініста; лекала були розроблені

РАЗРАБОТКА ОДЕЖДЫ ДЛЯ СКАЛОЛАЗОВ С ПОМОЩЬЮ ПРОГРАММ 3D-МОДЕЛИРОВАНИЯ

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Цель – исследовать целесообразность использования компьютеризированных программ виртуального моделирования одежды для разработки моделей мужских брюк для скалолазания.

Методология. Эксперимент включал сравнительные методы виртуального одевания, а также определение точек давления, перспективную карту и оценку внешнего вида. Теоретической и методологической основой исследования являются научные работы, представляющие данные по программному обеспечению для виртуального 3D-проектирования одежды.

Результаты. В работе выполнено сравнение размещения деталей и анализа внешнего вида трех конструкций брюк для альпинистов с помощью визуализации моделей на трехмерном манекене в программе CLO 3D. Технология 2D-to-3D была применена для разработки моделей одежды брюк альпибезпосередньо в програмному забезпеченні. Для моделювання була використана технологія 3D-анімації. Результатами дослідження стали: 1) 3D-моделювання трьох різних типів моделей штанів. 2) Оцінка якості посадки та комфортності одягу за допомогою карт облягання одягу. 3) Визначення найбільш дискомфортних частин деталей виробів на ділянках стегон, талії, низу штанів та обхвату колін. 4) Зміна та регулювання деталей одягу залежно від результату оцінки.

Наукова новизна полягає у наданні систематизованої методології використання тривимірного моделювання для розробки моделей одягу для певної категорії користувачів, таких як скелелази.

Практичне значення. Розглянуті напрями досліджень 3D-моделювання одягу можуть бути використані дизайнерами та виробниками одягу у творчому та експериментальному процесі проектування виробів, що розширює можливості програмного забезпечення для застосування функціонального дизайну в швейній галузі та наукових дослідженнях.

Ключові слова: *скелелазання; лекало штанів; віртуальна примірка; дизайн; 3D-моделювання; прототип.*

ниста; лекала были разработаны непосредственно в программном обеспечении. Для моделирования была использована технология 3D-анимации. Результатами исследования стали: 1) 3D-моделирования трех различных типов моделей брюк. 2) Оценка качества посадки и комфортности одежды с помощью карт облегания одежды. 3) Определение наиболее дискомфортных частей деталей изделий на участках бедер, талии, низа брюк и охвата колена. 4) Изменение и регулирование деталей одежды в зависимости от результата оценки.

Научная новизна заключается в предоставлении систематизированной методологии использования трехмерного моделирования для разработки моделей одежды для определенной категории пользователей, таких как скалолазы.

Практическое значение. Рассмотрены направления исследований 3D-моделирования одежды могут быть использованы дизайнерами и производителями одежды в творческом и экспериментальном процессе проектирования изделий, что расширяет возможности программного обеспечения для применения функционального дизайна в швейной отрасли и научных исследованиях.

Ключевые слова: *скалолазание; лекало брюк; виртуальная примерка; дизайн; 3D-моделирование; прототип.*

ІНФОРМАЦІЯ ПРО АВТОРІВ:

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