RIGA TECHNICAL UNIVERSITY

Inga DABOLINA

ANTHROPOMETRICAL MEASUREMENTS FOR THREE-DIMENSIONAL CLOTHING DESIGN

Synopsis of Doctoral Thesis

Riga 2010

RIGA TECHNICAL UNIVERSITY
Faculty of Material Science and Applied Chemistry
Institute of Textilematerials Technologies and Design

Inga DABOLINA
PhD student of the doctoral study program „Textile and clothing technology"

ANTHROPOMETRICAL MEASUREMENTS FOR THREE-DIMENSIONAL CLOTHING DESIGN

Synopsis of Doctoral Thesis

Scientific supervisor
Dr.sc.ing., professor
Ausma VILUMSONE

Riga 2010

UDK 687.1.021+004.92](043.2)
Dā 042 a

DABOLINA Inga Anthropometrical Measurements for Three-Dimensional Clothing Design. Synopsis of Doctoral Thesis-R.:RTU, 2010.-35 p.

Printed in accordance with the decision of the Institute TTD March 29, 2010, protocol No. 1

This paper has been worked out with the support of the European Social fund within the framework of the project „Support for the development of the RTU doctoral programme" of the National program „Support for the implementation of doctoral programs and after doctoral research".

ISBN …….

DOCTORAL THESIS
SUBMITTED FOR THE DOCTORAL DEGREE OF ENGINEERING SCIENCES AT RIGA TECHNICAL UNIVERSITY

The defence of doctoral thesis for doctoral degree in engineering sciences will take place at an open session on June 30, 2010 at 11^{00}a.m. of the Material science subject-field Textile and Clothing Technology in RTU promotion board P-11 Riga, Kalku st. 1, aud. 119.

OFFICIAL REVIEWERS

Professor, Dr.habil.sc.ing. Guntis Strazds
Riga Technical University, Latvia

Asoc. professor, Dr.sc.ing Mariana Ursache
"Gheorghe Asachi" Jasi Technical University, Rumania

Researcher of 3D scanning systems and services, Dr.sc.ing. Nicola D'Apuzzo
R&D Center "Hometrica Consulting", Switzerland

APPROVAL

I hereby confirm that I have worked out this doctoral thesis, which has been submitted for review for the acquisition of a Riga Technical University doctoral degree in engineering science. The doctoral thesis has not been issued to any other university for the acquisition of a doctoral degree.

Inga Dabolina __________________________

Date: April 1, 2010

The doctoral thesis has been written in Latvian and contains an introduction, 5 chapters, conclusions, a bibliography, 6 annexes, 48 figures, 9 tables, 132 pages of body text. The bibliography contains 110 titles.

CONTENT

INTRODUCTION 6

1. COMPUTER AIDED GARMENT DESIGNING 13

2. POSSIBILITIES OF ACQUIRING ANTHROPOMETRICAL DATA 16

3. LIMITATIONS OF HUMAN BODY 3D SCANNING 18

4. HUMAN BODY SURFACE LAYOUT POSSIBILITIES 21

5. DEVELOPMENT OF A MANNEQUIN AND DEFINITION OF STARTING DATA FOR 3D GARMENT DESIGNING 23

CONCLUSIONS AND RESULTS 26

BIBLIOGRAPHY 28

INTRODUCTION

The use of new information technologies and software provide the possibility to solve problems connected with raising work efficiency in the company. The first information on using a information technologies in the sewing industry, particularly in construction designing, turned up in the beginning of the 70-ies of the XX century, but first publications on computer aided designing software – only in the 90-ies of the XX century. At present most of the companies use computer aided software.

Modern computer aided designing software provides the possibility to avoid small operations and manual work, to raise precision, productivity and organize information flow. The usage of garment designing systems excludes the time consuming manual preparation of patterns, creation of layouts and relocation of written information. The computer systems are meant for the execution of every single process and the integration of all processes into one joint flow, for the organization of logistics and the mobility of work tasks.

The computerization of different processes in the garment industry is necessary to reduce the costs of a product and raise the competitiveness (Kang, a.o., 2000).

Computer systems allow making two dimensional as well as three dimensional product illustrations and visualizations. It is possible to create computer aided garment constructions, as well as gradations, and create a virtual first pattern of the model - such computer aided operations significantly decrease the time consumption and cost necessary to design a product. The costs of the product itself can be calculated with the help of the product management systems following the development parameters, the layout of patterns, textile expenditure, model complexity and specification, as well as previous experience of the company stored in a data base.

Although computer systems significantly facilitate the development of a product, the knowledge and skill of the user are still very important. One of the most important garment creation stages is constructing.

Constructing is the reproduction of a spatial model (clothing) on a plane (construction); this transformation has to be reflexive when joining the parts of the construction a garment is originated. The creation of the drafts of the construction is the most complicated and responsible stage of garment designing, because a non-existent complicated spatial shape product surface layout has to be created (drawn) (Vilumsone, 1993). One of the most topical problems in garment designing has always been the search of garment designing methods scientifically reasoned, precise and as little as possible time and labour consuming. Several factors depend on a precise development of garment surface layout – material expenditure, garment set quality, labour intensity level, the aesthetical and hygienic characteristics of the finished product.

The traditional mass production ever decreases the volumes of series, the production becomes more elastic and the choice of goods expands; the wear time decreases. Along with the serial production, individual production becomes more and more popular. The current economical situation shifts the search for labour more and more to the East, but the creation of individually oriented products could make it possible to maintain working places and production units in Europe. People will be willing to pay more for this type of clothing and receive it in a possibly short term. Thereby the promotion of individualized production is affected by social and economical aspects.

The non-contact anthropometrical data acquisition method is currently used to solve the problem of acquiring the clients' measures for individualized production, yet still the spread of individualized production is limited by the uniformity of assortment, the labour intensity of designing, the uncertainty of the result of the construction and the complexity of the constructing tasks creating an individual product for each customer.

Motivation of the doctoral thesis:

The theme of the doctoral thesis complies with the currents events in the garment designing industry, the research done so far are not able to provide complex effects of all parameters – a description of the manifold surface of individual human figures, the definition of spatial ease allowances.

Topicality of the doctoral thesis:

The quality of the product is determined during the designing process, therefore the development of new, modern methods and systems and software for garment designing is a topical task.

At present the world is looking for basically new garment designing methods, which could provide the creation of the most appropriate garment for each customer, using calculation methods. So far the garment designing praxis uses approximate surface layout methods, better known as pattern systems. The most progressive ones are based on the knowledge about the human body and characteristics of textile materials. Nevertheless since a non-existent spatial models' (garments') layout on a plane (construction) is being created, the reflexive transformation (a finished garment model) does not meet the expected results without further correcting actions (fitting and changing the pattern).

The industrial computer systems implement garment designing in a 2D environment; the existent 3D solutions are only meant for the control of the plane made patterns on a virtual mannequin.

Goal of the doctoral thesis:

Improving the means of 3D computer system anthropometrical data.

Tasks of the doctoral thesis:

1. To study and to analyze the computer systems and methods available for use and to perform a comparative analysis.
2. To study and to analyze the possibilities, systems and methods of acquiring anthropometrical data, to perform a comparative analysis.
3. To study, to identify and to classify the limitations of 3D scanning of a human body.
4. To study, to identify and to compare the possibilities of a 3D surface layout, compare methods.
5. To perform an experimental development of a 3D anthropometrical data mannequin, to give suggestions for the usage of 3D anthropometrical data in garment designing.

The practical significance of the doctoral thesis:

The results of the research have been used as methodical material for students in the Riga Technical University Textile technology and design institute.

The paper provides recommendations and includes universal criteria on how to choose a computer aided designing system with the goal to perform certain tasks; it is a compact information source for company owners for introducing computer aided designing systems into production.

The introduction of the developed suggestions on the human body scanning procedure will improve the precision of the data for the creation of a 3D mannequin.

The provided suggestions for the individualisation of the transversal plane configurations of parametric mannequins will allow achieving a better conformity of the virtual mannequin with the human figure.

Research methods of the doctoral thesis:

Basic approaches of trigonometry, analytical geometry and planimetry, applied mathematics, algorithmization and programming theory, plane layout theories, systematic analysis of the structure of complicated objects, comparative research methods, analysis of practical achievements in making computer aided garment designing systems, radial physics laws, complicated virtual shape surface description and approximation methods, photo measurement methods, computer graphics and computer modelling methods.

The experimental data has been acquainted and processed in the Vitus Pro human body laser scanner, in the Qualisys system for pace research, on a measurement stand allowing to determine the angular division of the reflected laser beam and its changes depending on the laser beam falling angle. The developed mathematical model of the mannequin has been created using the Delphi programming language.

Scientific innovation of the doctoral thesis:

A production process structural scheme has been developed identifying the processes of typal production with the goal to determine the mutual relationship of the production preparation processes and the structure of the informative means and the software.

Universal comparative criteria have been defined, qualitative and quantitative informative features; a comparison of the functional characteristics of computer aided garment designing systems has been performed.

An individualisation method with transversal plane configuration of the parametric virtual mannequin has been suggested.

Limitations have been identified to ensure the credibility of the results of the scanning process. An analysis of the oscillations during a stand has been performed and the frequency has been determined. It has been determined that different textile materials depending on the decoration have a different level of reflection from a diffused one to a mirror like reflection.

The coherence between the spatial ease allowance and the values of traditional allowances used in the calculation graphical methods. A possibility of using coordinate measurements of important points of dynamic postures for the determination of spatial allowances has been reflected.

A mathematical model of the virtual spatial human body mannequin has been developed, the initial information structure for its implementation has been determined.

Approbation of the doctoral thesis:

The main results of the doctoral thesis have been presented on 16 international scientific **conferences**:

1. The 4th International Conference on the Management of Technological Changes, Crete, Greece, 2005
2. 46th RTU scientific conference, Riga, 2005, Latvia
3. The 4th International Seminar on Quality Management in Higher Education, ROMANIA, Sinai
4. „3rd International Textile Clothing & Design Conference" 2006, 8-11 October, Dubrovnik, Croatia

5. The 5th International Conference Innovation and Modelling of Clothing Engineering Processes IMCEP 2007, Slovenia, October 2007.
6. 47th RTU scientific conference, 2006 Riga, Latvia
7. XI International Izmir Textile and Apparel Symposium, XI International Izmir Textile and Apparel Symposium, Turkey, Izmir, October 26 – 29, 2007.
8. CORTEP 2007, The XIII Romanian Textile and Leather conference, Romania, Iasi 2007
9. 48th RTU scientific conference, 2007 Riga, Latvia
10. Autex 2008, Italy, Biella, June 24 - 26, 2008
11. Magic World of Textiles, 4th International Textile, Clothing & Design Conference - Magic World of Textiles, Croatia, Dubrovnik, October 5 - 8, 2008.
12. 49th RTU international scientific conference, 2008 Riga, Latvia
13. VIII Conference on Optical 3D Measurement Techniques, ETH Zurich, Switzerland, July 9 - 12, 2007.
14. „The Challenge of Smart Fabric", What is the interaction potential of textile industry, design and modern technologies? Seminar in RTU, Latvia 15.02.2008.
15. International Scientific Conference UNITECH'09, Bulgaria, Gabrov, November 20 - 21, 2009
16. 50th RTU scientific conference, 2009 Riga, Latvia
17. The conference „Innovations in the textile industry in Latvia and in the World" April 9, 2010, Riga Latvia – moderator

The approbation of the paper has taken place using the theme account of **student training** examined within the framework of the doctoral thesis and working results in the following instruction courses:

1. MŠM378 Textile technology computer systems 2.0 CP (3 ECTS)
2. MŠM533 Computer aided designing of clothes 4.0 CP (6 ECTS)
3. MVR213 The designing computer system GRAFIS 4.0 CP (6 ECTS)
4. MVR214 The designing computer system LECTRA 4.0 CP (6 ECTS)
5. MŠM171 Development of industrial collections (study project) 2.0 CP (3 ECTS)
6. MŠM159 The photography method in garment designing 2.0 CP (3 ECTS)

The author of the doctoral thesis has taken part in 8 scientific research projects as a contractor or manager:

<u>International projects:</u>

1. „Project oriented training and teaching experience in Germany", February 1 – March 31, 2009, Germany, Latvia
2. „Innovation Transfer in Textiles" Leonardo da Vinci „Lifelong Learning Programme / Education and Culture DG", October 2008 – September 2010, contractor, UK, Greece, Romania, Portugal, Slovenia, Latvia
3. Nordplus Neighbour project "Nordic Centre for Innovative Studies and Advanced Training in Textiles", 2004 – 2007, Lithuania, Finland, Sweden, Latvia

<u>Other scientific research projects:</u>

4. "New guard uniform specification" LR AM JC – RTU L7319 February 11, 2008 – June 1, 2008, manager
5. „Acquisition of a garments' construction using the non-contact 3D anthropometrical modelling method", IZM – RTU R7348 01.03.2008 – 31.12.2008; responsible contractor

6. „Usage of the non-contact 3D positioning method in anthropometrical modelling”, IZM – RTU R7231 01.03.2007 – 31.12.2007; responsible contractor
7. Specification of tactical modular accoutrement of soldiers. Research ordered by the RL NAF Provision command. 2006, contractor
8. Improvements of quality of the uniforms of the NAF of RL. Research 6842 ordered by the MFA or RL. 2004, contractor

The author of the doctoral thesis is the author (and co-author) of 18 scientific research publications, 17 of which are published and 1 is submitted for publication. The results of the research performed within the framework of the doctoral thesis are reflected in international and other scientific publications acknowledged by the Latvian Scientific Board.

List of publications:

1. A.Vilumsone, I.Vilumsone**, I.Dabolina** Importance of a CAD course in the educating of new specialists. The 4th International Conference on the Management of Technological Changes, Crete, Greece, 2005, p. 243-248.
2. **I.Dabolina**, A.Vilumsone, S.Deksne. Improvement of the daily and festive uniform models of the NAF. RTU 46th international scientific conferences' compilation, 2006, p. 67 – 73.
3. A.Vilumsone, S.Deksne, **I.Dabolina**. Automatization of the construction process of daily and festive uniforms of the NAF, RTU 46th international scientific conferences' compilation, 2006, p. 74 - 81.
4. Vilumsone A., Vilumsone I., **Dabolina I.,** Deksne S. THE IMPORTANCE OF CLOTHING FASHION SHOW IN THE STUDY PROCESS // The 4th International Seminar Quality Management in Higher Education QM 2006, The 4th International Seminar on Quality Management in Higher Education, ROMANIA, Sinai, June 6 - 10, 2006. p. 56-62.
5. Ausma Vilumsone, Ineta Vilumsone, **Inga Dabolina** & Skaidra Deksne. Design Improvement of Military Uniforms. „3rd International Textile Clothing & Design Conference” 2006, October 8 - 11, Dubrovnik, Croatia, p. 931 - 935.
6. Razdomahins N., Vilumsone A., **Dabolina I.,** Computer designing in garment production, RTU Scientific articles. 9th edition, Material science. Textile and clothing technology. Volume 2, RTU, 2007, p. 111 - 116.
7. **Daboliņa I.,** Vilumsone A., 3D anthropometrical modelling // RTU Scientific articles. 9th edition, Material science. Volume 2. (2007), p. 103 – 110.
8. Vilumsone A., **Dabolina I.** THE POSSIBILITIES OF GARMENT 3D DESIGNING // Proceedings of XI International Izmir Textile and Apparel Symposium, XI International Izmir Textile and Apparel Symposium, Turkey, Izmir, October 26 - 29, 2007. p. 161 – 171.
9. **Dabolina I.,** Vilumsone A. Anthropometrical modelling for garment manufacturing, CORTEP 2007, The XIII Romanian Textile and Leather conference, Romania, Iasi 2007, p. 635 – 641.
10. **Dabolina I.,** Blums J., Vilumsone A., Research of laser beam flow reflection on linen materials // RTU scientific articles. 9th edition, Material science. – Volume 3 (2008), p. 62 – 70.
11. **Dabolina I.,** Vilumsone A. Application of non-contact anthropometrical measurements for garment construction // electronic source, Autex 2008, ITALY, Biella, June 24 -26, 2008. p. 1 – 7.

12. Vilumsone A., **Dabolina I.** The Estimation and Approbation of 3D Garment Designing and Photo Measurement Method // Book of proceedings of the 4rd International Textile, Clothing & Design Conference – Magic World of Textiles, 4th International Textile, Clothing & Design Conference - Magic World of Textiles, Croatia, Dubrovnik, October 5 - 8, 2008. p. 676 – 681.
13. **I.Dabolina**, A. Vilumsone; Automatically gained anthropometrical data for garment CAD. International Scientific Conference UNITECH'09, Bulgaria, Gabrova, November 20 - 21, 2009. Volume II p. 327 – 333.
14. **I.Dabolina,** A.Vilumsone, The Limitations of Automatically Gained Anthropometrical Data; Proceedings of the Annual Symposium of Knitting and Clothing Specialists „Textiles of the Future", CD, p. 9, Technical University from Iasi, Faculty of Textile - Leather and Industrial Management, December 4 – 5, 2009, Iasi, Romania.
15. **I.Dabolina,** A. Vilumsone, A.Fjodorovs; Application of Non-contact 3D Positioning for Anthropometrical Modelling, p. 8. 49th RTU scientific conference, Riga, Latvia.
16. **I.Dabolina**, I.Sahta, G.Terlecka; The usage of digital measuring-tape in garment production. p. 7. 49th RTU scientific conference, Riga, Latvia.
17. **I.Dabolina,** A.Vilumsone, The Application Possibilities of 3D Systems for Garment Development, 41th International Symposium on Novelties in Textiles, May 27 – 29, 2010 in Ljubljana, Slovenia.

<u>Accepted for publication:</u>

18. **I.Dabolina,** A.Vilumsone, J.Blums; Investigation of Textile Materials for Laser Light Beam Scanning, 9th International Conference on Global Research and Education Inter-Academia August 9- 12, 2010, in Riga, Latvia.

The main research directions of the doctoral thesis: to study and to analyze garment designing and anthropometrical data acquisition methods, systems and techniques; to improve the means of 3D computer system data using modern technologies.

The doctoral thesis consists of five basic chapters, an introduction, results and conclusions, an explanatory and an abbreviation dictionary are included, as well as a list of figures and tables.

The introduction gives an insight into the problems of the paper, the topicality of the research is justified, the goal and the tasks of the paper is defined, the approbation of the thesis is described.

The first chapter studies, analyzes, classifies and compares garment computer designing methods and systems; it reviews the interaction, characteristics and problems of garment designing basic processes and system components.

The second chapter studies, systemizes and analyzes methods, systems and possibilities of anthropometrical data acquisition. It reviews and analyzes the possibilities of combining different methods and gives a comparison of the methods. Different data acquisition devices are analyzed and their suitability for the acquisition of a human body surface description and measures.

The third chapter of the doctoral thesis studies and analyzes the limitations of 3D scanning of a human body, provides an analytical review, identifies possible solutions.

Chapter four summarizes and analyzes methods of the human body surface layout methods with the goal to identify the possibilities of laying out the surface of a garment defined in a 3D environment.

Chapter five describes the implementation possibilities of an experimental 3D mannequin, provides a description of the implementation, and outlines the approach to further implementation of 3D garment designing basing on an individualized virtual mannequin.

The results and conclusions of the doctoral thesis are summarized in the final part of the doctoral thesis.

1. COMPUTER AIDED GARMENT DESIGNING

Computer aided designing software not only provide the possibility to speed up the process of putting a new model into production and improve the quality of the products, but also to reduce material costs and labour intensity, ensuring an elastic change of the assortment. Most of the systems are made by the module principle in which separate garment designing stages are implemented. The systems are constantly being developed according to the improvements of in production conditions, the implementation of new technologies as well as the optimisation of the designing process.

Reviewing some of the computer aided garment designing (CAD) systems a comparison of the functions has been performed serving as universal comparative criteria, informative indications: development of technical documentation, artistic designing of a model, constructing and modelling, creation of pattern layout, integration of individual measurement tables, integrated constructions, calculation graphical designing, automated formatting of patterns, 2D designing, 3D designing, 3D imitation. Such criteria and indications allow performing a comparison of the functional characteristics of computer aided garment designing systems. Twenty two systems have been compared and analyzed.

When introducing CAD/CAM systems, some main aspects have to be taken into consideration: costs of software, equipment, technical supply and training, the suitability to the particular production conditions, the safety of exploitation and improvement possibilities. Although the implementation of systems is an expensive process, the advantages compensate the high costs and difficulties that arise during the implementation.

Modern computer aided designing systems allow performing different designing stages including traditional 2D designing, as well as the imitation of a 3D garment, 3D virtual fitting.

Modern 2D CAD/CAM systems perform constructing in three ways:

Type 1 The construction is designed manually, but the production preparation is performed using computer technologies (manually prepared patterns are entered into the system with a digitizer).

Type 2 Manual work is completely excluded. The whole designing and preparation process is computer aided.

Type 3 Part of the designing stages are computer aided, without human help, but the rest is an interactive process.

The use of any kind of computerization has indisputable advantages: improved production quality, higher productivity, humanization of the working process, more elastic production, process control, the possibility to link the production with the desires of the customer (rapid response). Nevertheless each system can be improved. For a 3D imitation of a garment to adjust a parametric mannequin to the individual measures of a human body additional projection body measures have to be considered (at present only the height is integrated, but the width characterizing the configuration of transversal planes is necessary too.

The latest tendency in the CAD/CAM development is the creation of 3D designing. There are several reasons for the implementation of 3D designing:

- plane-like garment designing methods do not provide an absolute conformity of the garment with the expectations;
- the construction of garments in opposition to the object (garment) to be designed is a plane-like process – it does not provide a preview of the product. In its turn the preparation of patterns is an expensive and time consuming process;
- the 2D visualizations of the garment do not provide the evaluation of the characteristics of textile materials.

Although 3D designing where it is possible to create a layout of plane details by a 3D shape drawing already exists, such systems have several disadvantages: a limited assortment and shape of garment, segmentation.

Depending on the practicable task, 3D systems can be divided as follows:

Type 1 Imitation of the garments' appearance – the system allows to change the 3D sketch or photograph to evaluate the appearance of the garments' model with visually different types of textile materials;

Type 2 Garment imitation – the systems allows performing a virtual fitting, evaluate the external appearance, shape, set, proportions of the garment (the garment is created in 3D by joining patterns constructed in a plane, creating an imitation of the garment with the intention to ascertain the conformity of the outer appearance to the expectations);

Type 3 Garment designing – the system allows creating the shape of a garment, identify (define) dividing lines, create patterns in a 3D environment following a layout in a plane.

One of the currently used designing software products is the STAPRIM system created in Russia, which allows creating a garment for particular customer in a 3D environment and acquire constructions of details. Such a system could be very suitable for the creation of different uniforms, since it allows creating well set constructions for different individual figures, but the result provided by the system is a basic construction and does not foresee full designing of special features of a model. Importing this construction into any other system the model construction and pattern designing process has to be started anew. Therefore it is advisable to develop an algorithm providing the inheritage of detail size and shape of individual figures up to the level of finished patterns (as it is, for example, in the software GRAFIS).

There are several other 3D designing elaboration foreruns and finished elaborations, the usage of which is limited by different factors – assortment, segmentations of products, the fiction of 3D designing – all changes are made in a 2D environment.

The paper analyzes the operation of garment imitation systems and gives suggestions for an individualisation method of the parametric virtual mannequin. Since the adaptation of the virtual mannequin to the customer is usually performed using anthropometrical perimeters and lengths, the acquainted individual mannequin does not always conform with the natural shape of the human body. To try to solve this problem it is advisable to introduce the possibility to evaluate the "crosscut" of the body, especially the possibility of configuring transversal planes by changing the diameter of elliptical shapes in a way that the system automatically saves the perimeter of the ellipse.

A structural scheme of the production process, identifying the processes of typal production with the goal to determine the mutual relationship of the production preparation processes and the structure of the informative and software means, has been developed; it has been concluded that no matter what level CAD/CAM system is used, their usage provides a faster development of the product and shortens the working process. A complete 3D designing process would exclude different working stages connected with constructing and constructive modelling, 3D imitation and creation of a virtual prototype.

2. POSSIBILITIES OF ACQUIRING ANTHROPOMETRICAL DATA

There are two types of human body measurement acquiring methods:

Type 1 manual anthropometry methods (contact methods);

Type 2 optic anthropometry methods (non-contact methods).

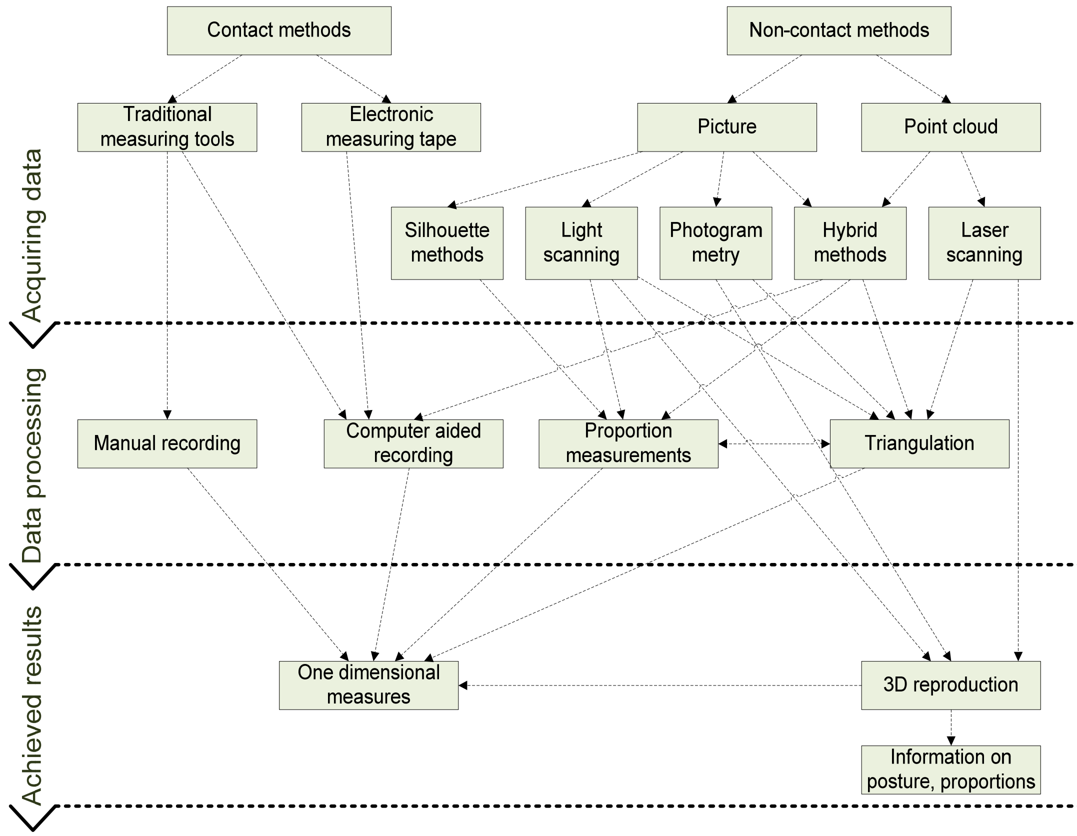


Figure 1 Types of anthropometrical data acquisition

Anthropometrical data can be acquired with different tools. Traditional methods use different manual tools (measuring tape, anthropometer, a.o.). as the technologies develop, new tools are created and/or the existent ones are improved. The electronic measuring tape can be considered as an improvement of the electronic measuring tape, but its use for anthropometry is doubtful. It has been proved by an experiment that when using the electronic measuring tape, more than half of the measures taken were wrong.

Photo measuring methods are fast and effective, but the processing of data is time consuming and labour intensive. A relatively new tool (approximately since 1980 (Fan j., 2004)) in anthropometry is the 3D scanner.

Considering the advantages of 3D scanning, the scanning technologies are being developed and improved. Most of the scanners can not only create a 3D image of the human body, but also read the x, y and z coordinates thereby acquiring precise information about the human body an its volumes. (Hwang, 2001)

A human body surface reproduction dot cloud is created from the coordinate readings, which can be used as a virtual mannequin or only the coordinates themselves can be used. A virtual reproduction of the human body can be used in garment production, car production, engineering and medicine.

Any scanning device is equipped with optic (light) appliances to ensure non-contact measuring. Such optic measurement acquisition devices can be divided into categories: photogrammetry, silhouette methods, laser scanning, light projection, electromagnetic wave and hybrid methods.

Each method has its advantages and disadvantages. In spite of the fact that laser scanning has been recognized as the most precise method and the gathered results are the most extensive (human body measurement data, a 3D virtual mannequin, a reflection of the actual texture, surface relief measurements, etc.), the light projection method is used more widely in the garment production industry since the equipment is much more cheaper than a laser scanner.

Comparing different anthropometrical data acquisition methods, the paper defines universal comparison criteria, qualitative and quantitative informative features: measures of the whole body at once, choice of the size of garment, creation of a 3D virtual mannequin, free (public) access, no postures, sizes and other limitations, data acquisition precision, data acquisition time, data processing time, computerization of data acquisition, no special equipment, easy to transport, easy to set up, low equipment cost. Such criteria and features allow performing a comparison of different anthropometrical data acquisition method functional characteristics. Following methods have been compared and analyzed: manual measurements, measurements with an e-measuring tape, photogrammetry, silhouette methods, laser scanning, light projection, electromagnetic wave method, and hybrid systems.

There is still not enough research and results as to use virtual mannequins for 3D garment designing. Mostly 3D scanning results are used to generate measures used in tailoring to use them in traditional or computer aided constructing methods.

3. LIMITATIONS OF HUMAN BODY 3D SCANNING

3D scanning of the human body can be used successfully in computer aided garment designing and individualized production. Nevertheless the scanners have to be improved considerably – the data acquisition time has to be shortened, the way of displaying the scanned data has to be improved, the 3D scanner software has to be improved, a.o.

The scanning technologies are being improved constantly, the price has falls considerably comparing to previous developments, nevertheless each system has individual imperfections.

Although it is possible to enumerate the deficiencies of each system, their data precision is sufficient so that 3D scanners can be considered as appropriate for anthropometrical data acquisition for garment designing.

Two researches connected with the limitations of 3D scanning have been described:

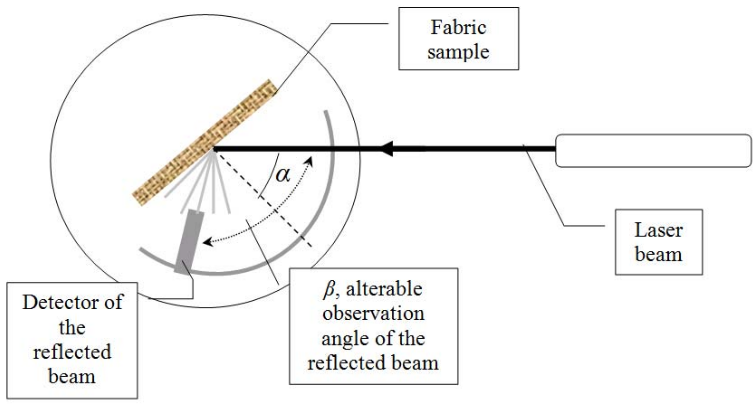


Figure 2 Scheme of the reflection study experiment

The scanning systems for human body measure acquisition use different data acquisition ways: dynamic range (lights and darks), laser beams, a.o. The experiment determines the laser beam reflective abilities of different textile materials and the curve characterising the reflectivity has been compared to the Lamberts' law diffuse reflectivity curve.

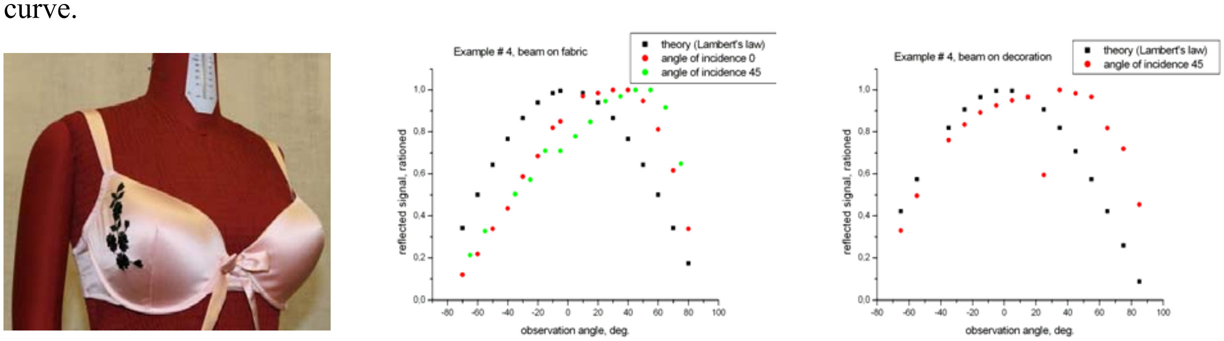
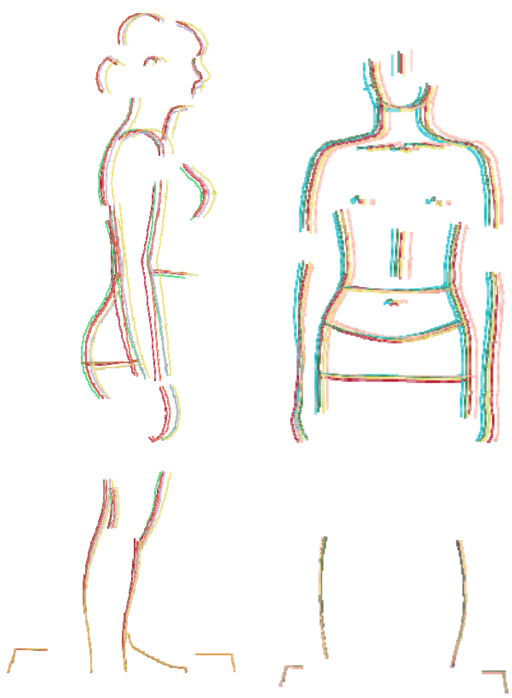


Figure 3 An example of the results of the reflectivity study experiment: If the beam falls on a decorative element deviations from the diffuse division can be observed, this can be due to the brightness of the fabric. In this case there are significant changes in the division and a fall of the signal almost to the zero level has been observed (40 degree angle).

Studying the light reflections from different fabrics, essential deviations from the Lambert law were observed. Such deviations come from the geometry of the fabric surface (relief, texture, trim). Insignificant deviations from the standard curve can be observed on very smooth (bright) surfaces and uneven (relief) surfaces. Decorative elements – embroidery, applications can cause a too bright and uneven surface causing deviations from the standard division in these areas. If the underwear is decorated with crystals or other very bright materials, the reflection curve is very uneven with several extreme points. The reflectivity of different textile materials depending on the decoration varies from diffuse to mirror-reflectivity.

As a result of the research it can be concluded that a smooth, but not bright underwear, without any decorative elements, has to be chosen for scanning. Underwear with decorative elements that can reflect or brake the ray of light – crystals, glass particles, pearls – should be used under no circumstances.



A *B*

Figure 4 Change of the posture (analysis of five sequential positions): a) side view, b) front view

An analysis of the oscillations of the human body in rest state has been performed and the significance of these oscillations for 3D anthropometrical measurements has been studies.

The experiment has been performed for three different postures of a person: back view, side view and front view. Since the front and back view analysis did not show any differences, the result of the analysis has been reflected for the side view and front view only. Photographing has been performed in two cycles.

In the first cycle differences in the posture have been evaluated photographing the person in one and the same posture every three seconds, for each posture. Afterwards the changes in the posture were analyzed. The analysis of the front view and back view postures show little change in the posture. A person can oscillate in the range from 3 to 12 mm.

The side view oscillations are greater – those can vary in the range from 9 to 21 millimetres. Such a difference can be explained by the fact that ankles are more likely to move back and forth than sideways. The results of the analysis show that the volume of oscillations increases the higher the person is from the ground. In this case not only oscillations, but small changes in the positioning of the body and posture have been observed.

In the second photo analysis cycle posture changes were evaluated sequentially stepping off the platform and changing the position of the feet and the body by 90º as it is in scanning devices with change of posture. The range of the oscillations of the front and back views is from 10 to 40 millimetres, in its turn the side view oscillation range is from 11 to 51 millimetres while the feet and the ankles remain in a fixed position. Such oscillations are characterized not only by the change of posture, but also by the change of the stand and corpus position. The changes can affect the scanning process causing inaccuracies in the data.

3D scanning has several advantages comparing to manual measurements – it is fast, sequential, and has a higher precision level. Using 3D scanning, no professional knowledge is needed to acquire the measurements – most of the systems generate the measures of the human body self-dependently. What makes 3D scanning so attractive is the fact that is a non-contact method, but it also has disadvantages – most of the systems cannot determine hidden areas (armpits, chin, a.o.), as well as vague scanning contours. The latter one is mainly affected by the oscillations of the body in time. Therefore the scanning time should be shortened as much as possible.

4. HUMAN BODY SURFACE LAYOUT POSSIBILITIES

The surface of the human body is an object that cannot be laid out due to the vagueness of its surface and different variations. The human body consists of many different geometrical figures, it is a complicated shape and its laying out is a complicated process.

The chapter describes the possibilities of laying out the surface of a mannequin or human body, dividing it into geometrical shapes which are possible to reproduce in a plane.

With the development of 3D surface acquisition and lay out methods the triangle method is used most of the time. It is a plan base point web creation method, where the base points are placed in a way that they shape a mutually linked triangle system.

Base points are put on the irregular surface of the human body and then triangle plane points are being searched to be able to lay out the surface in a plane. This way it is possible to lay out a spatial surface in a plane.

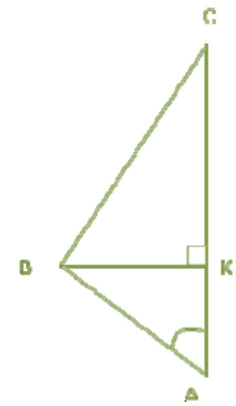


Figure 5 Example of a triangle

To create a spread triangles are taken sequentially. Necessary data for each triangle is calculated (length of the edges, angles). Each peak of the triangle has the x, y and z coordinates. Wherewith it is possible to do calculations (see triangle example in figure 5).

$$AB = \sqrt{\Delta x^2 + \Delta y^2 + \Delta z^2} \quad (1)$$

where

$$\Delta x = x_A - x_B \quad (2)$$

Similarly it is possible to calculate the length of all edges (AB, BC, AC), Knowing AB, BC and AC it is possible to calculate the Cos α of the triangle for the angle shown in figure 5:

$$Cos\ \alpha = \frac{AB^2 + AC^2 - BC^2}{2 * AB * AC} \quad (3)$$

Knowing the Cos α, the height KB of the triangle can be determined.

When performing the triangulation for the layout of s surface, the triangle arrangement principle is very important. The principle of extremes is used most of the time, where the peaks of the triangles are determined by the highest and lowest points in the nearest area, previously defining the maximum distance between the points. The higher precision wants to be achieved and the more spherical the surface, the smaller the lengths of the triangles have to be.

The geodesic method is also used to lay out the surface of the human body. The layout is created for the part of the surface marked by the geodesic lines. It is important to choose correct directions of the lines, the distance between them, as well as to consider the perpendicularity in the centre of the surface. Expressing it mathematically – geodesic lines are the generation of straight lines on a curved surface. Such lines are drawn with an inkling of that they are straight – namely two dimensional, they can be described with the help of the coordinates of the plane. A straight line drawn on a spherical surface, depending on the spherical level, creates one of the curved lines function (spline, hyperbole, etc.).

The plane splitting method uses the possibility of laying out geometrical planes. Each of the surface details isolated on the figure is equalled to a geometric surface which is laid out in a plane afterwards. The process consists of three stages: studying of the surface determining the splitting areas, determination and measuring of the splitting planes, drawing the spread.

The plane splitting method does not have a particular shape of the figures allowing free improvisation depending on the regularity of the surface or contrary – irregularity. That way this method as if combines the triangulation method and the geodesic line method.

Comparing the results of method usage and the workflow it can be concluded that none of the manually executable methods provides a precise result, the plane splitting and geodesic line method do not provide information about a rational positioning and size of seams, in its turn the triangulation has to be performed with small triangles so its usage and result would be appropriate. Besides as a result of the usage of the plane splitting and geodesic line methods surface describing plane parts with curved lines are acquired, not allowing to connect them properly. Nevertheless considering the possibilities of computerization it is being considered that the triangulation method describes the surface the best. Besides the triangle is the only plane shape that is unequivocal (it is only possible to draw one plane through three points without bending or breaking it). Therefore triangulation can be considered as the most precise engineering method for displaying a spatial surface in a plane.

5. DEVELOPMENT OF A MANNEQUIN AND DEFINITION OF STARTING DATA FOR 3D GARMENT DESIGNING

The designing of clothes includes a row of processes and one of the most time and labour consuming is constructing. A construction displays the layout of the surface of the body (garment). At present the existent garment construction ways do not provide a possibility of creating a garment without fitting, besides the plane-like projection process of a spatial object demands high level skill, imagination and creativity from the constructor. Similarly the traditional human body measurement acquisition methods do not provide the acquisition of correct entry data. Therefore 3D designing is necessary with options like:

- Usage of a 3D virtual mannequin in designing – the optic human body measurement acquisition methods unbar the possibility to create a 3D mannequin automatically (Siegmund , a.o., 2007). That will exclude the need for manual measurements.
- 3D spatial allowance designing, ensuring the comfort of the garment as well as the clarity of the visual design, excluding setting, which is a very labour intensive process with interactive repetitions.
- A visually graphic designing process – the possibility to evaluate the external looks of the garment would exclude the necessity of creating expensive patterns.
- The possibility to create details of the garment in a 3D environment following a layout in a plane.

Such a designing process can be defined as a scheme of some actions:

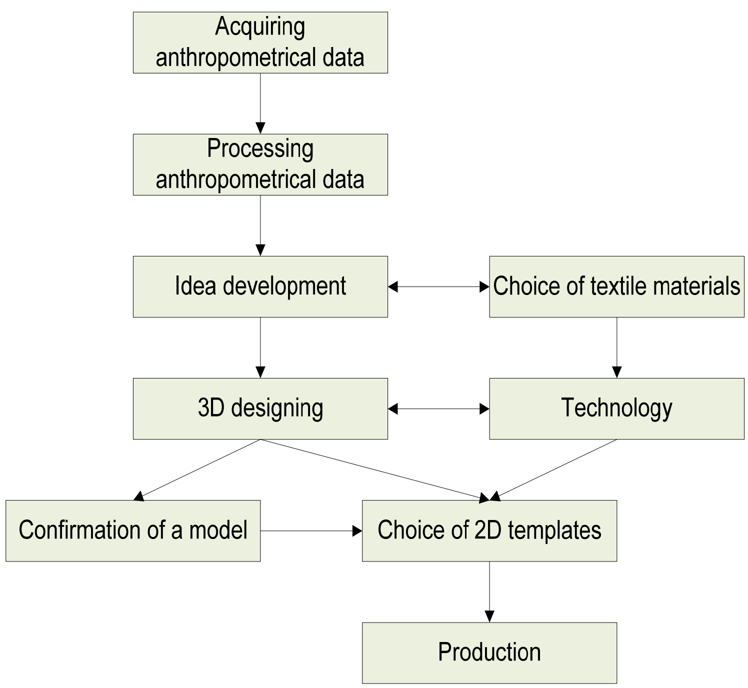
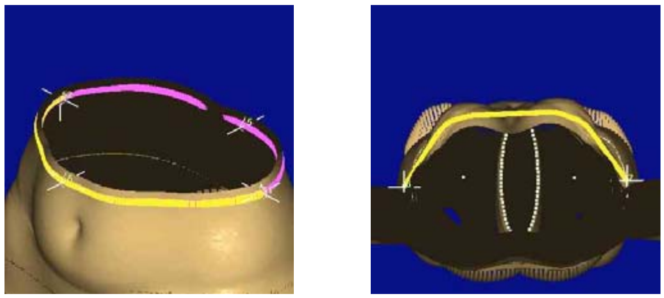


Figure 6 The 3D process of garment designing

To implement the technology that would allow designing clothes in a 3D environment, it is necessary to use an effective method for acquiring human body measurements, which would be appropriate for creating a digital model of the human body on a computer.



A B

Figure 7 Acquiring anthropometrical measurements: a) waste girth, b) breast width

3D parameters, information on the posture and proportions, as well as the measures used in tailoring are all acquired using a scanner.[1] The anthropometrical measures are acquired with the help of perimeter splits of a virtual mannequin, measurements of intermediate anthropometric point straight lines, as well as in the result of a combination and approximations of these versions (in case of breast width measurements a.o.) (Human Solutions)(Figure 7).

3D data in three resolution levels are achieved after processing the data – the lowest resolution (~26 000 dots), highest resolution (~70 000 dots) and a 3D mannequin with texture. Two types of parameters are acquired in each file:

- The x, y and z values of the 3D coordinates (marked with the letter *v*),
- The connection sequence of triangles (marked with the letter *f*).

The body surface point coordinates acquired by scanning are used to develop a 3D mannequin. The file with the coordinate parameters is saved and sub-files for point

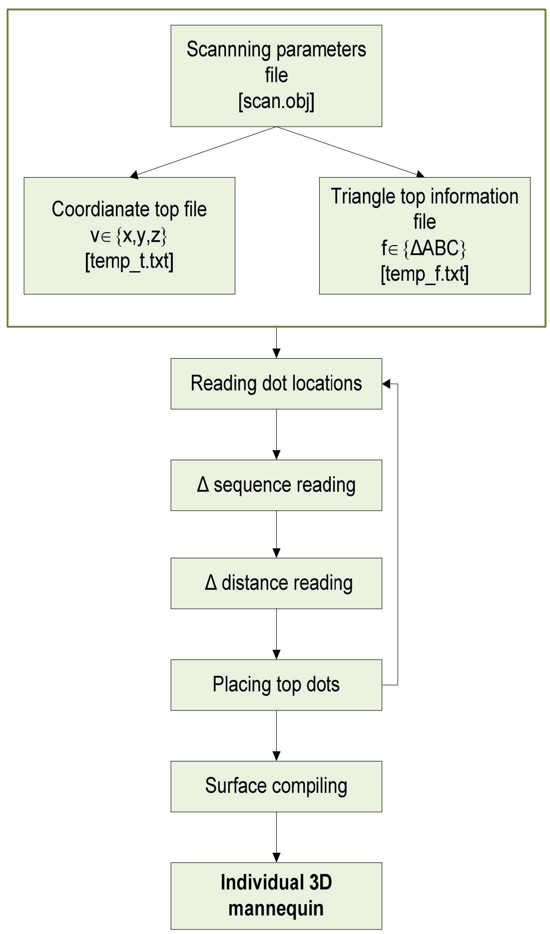


Figure 8 Creation process of a 3D mannequin

[1] The human body laser scanner VitusPro has been used to perform an experiment for 3D data acquisition. The research has been performed in cooperation with the scientific research laboratory of the University of Switzerland MiraLab. Switzerland, Geneva. 18.05. - 21.05.2008.

coordinate and triangle position determination are created. After this process the system cyclically reads the positions of points, the sequence and distances of triangles and places the points. The mannequins' surface is compiled from the placed dots and the individual 3D mannequin is created.

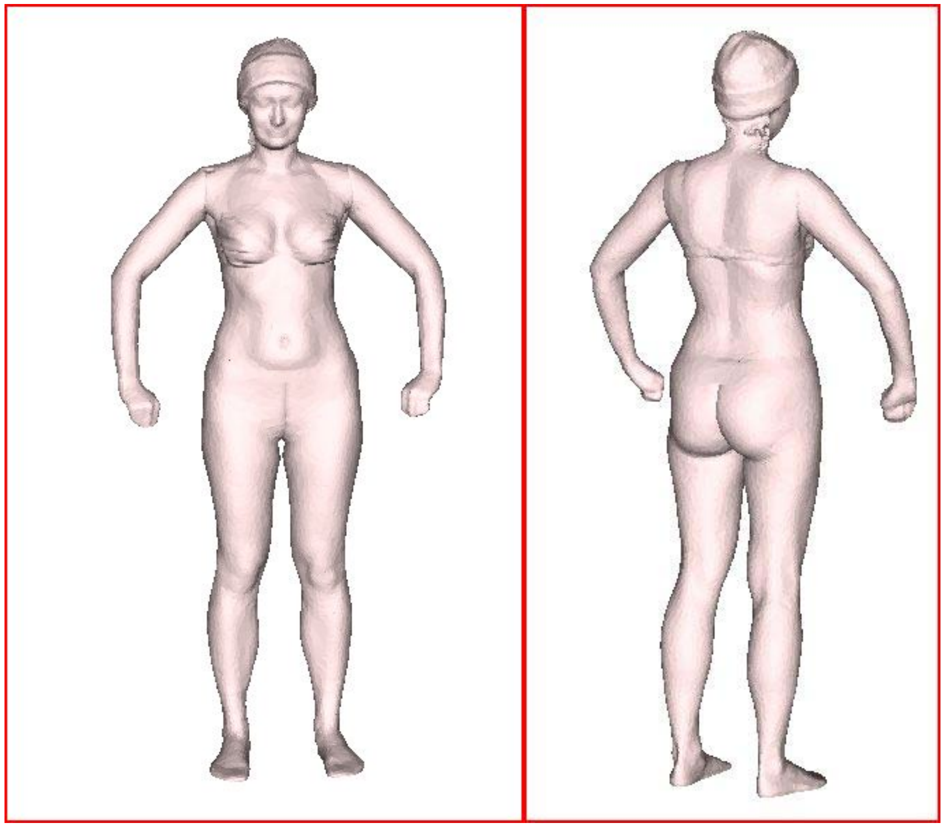


Figure 9 The created 3D mannequin

To create the surface of a garment it is necessary to determine the values of spatial allowances, which are defined as the distance between the garment and the surface of the body. To calculate these, traditionally used allowances can be used, or partially particular anthropometric point measurements in dynamics. The paper determines the coherence between the values of spatial allowances and traditionally used allowances. The paper also shows a possibility of using anthropometrically important point coordinate measurements of dynamic postures for the determination of ease allowances.

The 3D mannequin development system has been approbated by creating a virtual mannequin from the scanned data. A description of the creation of the geometric shape of a virtual mannequin has been developed. The spatial mannequin matches the actual body; the acquired measurements do not have significant deviations from the real ones. The developed 3D mannequin can be used in further research creating a 3D designing system.

CONCLUSIONS AND RESULTS

Basing on a literature study and a systematic analysis of the structure of complicated objects, the paper justifies the necessity to design clothing in 3D computer systems and gives suggestions on using anthropometrical data in 3D clothing designing, identifies 2D and 3D designing types.

Basing on the algorithmization theory a structural scheme of the existent production with two dimensional designing means has been developed, as well as a structural scheme with three dimensional designing; a comparative analysis of both has been performed.

A systematization of the 3D garment designing process has been performed. A recommendable sequence of the process is given. In case of a successful development of the research it is meant to bypass a row of time consuming processes: designing the basic construction of a garment and following adjustments. A further development of such a system would provide several advantages: the predictability of the shape and set, thereby exterminating routine work of the constructor and giving the possibility to work creatively with a real body anthropometrical data web.

As a result of the analysis of the existent clothing designing process, its methods and techniques it has been concluded that a 3D garment designing system has to be equipped with a 3D mannequin, a spatial allowance system and clothing surface definition means.

The starting data of 3D designing have been systemized: spatial virtual mannequin, spatial allowances (comfort and modern), clothing coordinates; and their determination procedure have been defined. Examples for the recalculation of traditionally used allowances have been given.

Computer aided clothing designing and anthropometrical data acquisition possibilities available for use, systems and methods have been studied and analyzed in the paper.

The possibilities of 3D human body scanning have been studied, identified and systemized, characteristics have been given and an analysis of possible combining has been performed. Methods of a 3D surface lay out have been studies, analyzed and compared.

The paper studies different possibilities of human surface lay out, and mannequin surface lay out engineering methods have been tested. The layout of a bodies' surface is necessary to determine the parameters of an object (in aspect of this paper – clothing). Since it is not possible to define particular individual geometrical figures of which the human body, and wherewith the clothing surface, consists it has been concluded that triangulation can be considered as the most precise engineering method for the reproduction of a surface in a plane.

Information on 3D human body data acquisition possibilities has been systemized, limitations of data acquisition methods have been analyzed and it has been concluded that individual methods (for example the photo measurement method) are not comfortable for a person due to ethical reasons – images are made and their further processing is not discrete. It has been determined that the precision of the scanning results depends on the scanning time and number of postures necessary for scanning. For laser scanning it is advisable to wear smooth, not bright underwear to avoid the appearance of unread or incorrectly read areas of the body covered by underwear.

An algorithm for the development of the geometric shape of a virtual mannequin has been worked out. The spatial mannequin matches the actual body, the measures do not have essential deviations from the actual ones. The created 3D mannequin allows developing a 3D designing system in further research.

Using geometry, planimetry and trigonometry methods:

- Mistakes of scanning parameter acquisition due to oscillations of the human body during scanning have been described; a calculation of the perimeter of the two ellipses has been given;
- The disadvantages of the existent parametric mannequin individualization possibilities have been described, suggestions for the prevention of these deficiencies have been given;
- The methodology of spatial allowance acquisition has been described;
- The methodology of three dimensional dynamic anthropometrical research has been described;
- The process of the development of a virtual mannequin has been described.

A new system for the development of a 3D mannequin from scanned data has been worked out containing two parameters – a description of the coordinates in the x, y and z ordinate axes and the sequence of triangle top positioning.

The graphic editor has been created using Delphi programming language, it can be used individually or as a part of the laser scanner. The system has access to the graphical language and system means menu charts which are understandable to the designer without having previous knowledge in programming.

The results of the thesis will be used in Riga Technical University Textile Material Technology and Design institute as methodological material for student training and further research on improving the process of garment designing.

BIBLIOGRAPHY

3D Ouest Ltd. [Live]. - Korux human body laser scanning technology. - www.3douest.com. - France.

3D-Shape GmbH [Live]. - Body and Face Scan Stripes projection technology. - www.3d-shape.com. - Germany.

4D Culture Inc. [Live]. - 4D Culture 3D human body laser scanning system. - www.4Dculture.com. - South Korea.

AceApparel CAD/CAM [Live] // Clothing designing. – the company was established 2001 by Mo Deok Won. - www.pattern-cad.com.

Assol CAD/CAM [Live] // Clothing designing. - Centre of Applied Computer Technologies ASSOL; Moscow Institute of Physics and Technology, Dr. Gennadij Andreev. - www.assol.mipt.ru.

Assyst CAD/CAM [Live] // Clothing designing. - Assyst-bullmer. - www.assyst-intl.com.

Audaces CAD/CAM [Live] // Clothing designing. - fashion technology. - www.audaces.com.

Auzukalns J. [a.o.] Tehniskā grafika/ Technical Graphics [Book]. - Riga: Zvaigzne, 1994. - p. 191.

Beazley Alison un Bond Terry Computer-aided pattern design & product development [Book]. - UK: Blackwell Publishing, 2003. - p. 220. - ISBN 1-4051-0283-7.

Bernina [Live] // Clothing designing. - OptiTex/Siemens#3: FIT Technology Bernina MyLabel. - www.berninamylabel.com.

Bodymetrics Ltd. [Live]. - 3D body data analysis software. - www.bodymetrics.com. - UK.

Buxton Bernard Dekker Laura, Douros Ioannis, Vassilev Tsvetomir Reconstruction and Interpretation of 3D Whole Body Surface Images [Report]. - Gower Street London : Department of Computer Science University College London, 2006. - WC1E 6BT United Kingdom.

CAD Modelling Ergonomics S.r.l. [Live]. - Antrophometrics dummies by silhouette extracting technology. - www.cadmodelling.it.

Comtense CAD/CAM [Live] // Clothing designing. - © Комтенс. - www.comtense.ru.

Cyberware Inc. [Live]. - Cyberware whole body 3D laser scanner technology. - www.cyberware.com. - USA.

D'Apuzzo Nicola Feasibility study: Full Body Scanning, Virtual-Try-On, Face Scanning, Virtual-Make-Over with application in apparel. [Report]. - Zürich, Switzerland: Hometrica Consulting, 2008.

D'Apuzzo Nicola Recent Advances in 3D Full Body Scanning With Applications to Fashion and Apparel [Article] // Optical 3-D Measurement Techniques IX. - Vienna, Austria: [no title], 2009. - p. 10.

D'Apuzzo Nicola Surface Measurement and Tracking of Human Body Parts from Multi Station Video Sequences [Report]: Doctoral thesis. - Zurich: Swiss Federal Institute of Technology Zurich, 2003. - p. 148. - ISSN 0252-93355; ISBN 3-906467-44-9.

Dāboliņa I., Blūms J. and Viļumsone A. LĀZERA STARA PLŪSMAS ATSTAROŠANAS IZPĒTE VEĻAS MATERIĀLOS/ A study of the laser beam reflections on underwear materials [Magazine] // RTU scientific articles. - Riga: Riga Technical University, 2008. – part 9: Material Science 3. - p. 62-70 - ISSN 1691-3132-2008-3132.

Dāboliņa Inga and Viļumsone Ausma Trīsdimensiju antropometriskā modelēšana/ Three dimensional anthropometrical modelling [Article] // RTU scientific articles, 2007. - Part 9: Material Science, Vol. 2, p. 103-110. - ISSN 1691-3132-2007-2.

Dāboliņa Inga, Šahta Ingrīda and Terļecka Gaļina Elektroniskās mērlentes lietošana apģērbu ražošanā/ The usage of digital measuring-tape in garment production [Magazine] // RTU scientific articles. - Riga: Riga Technical University, 2009. – Part 9, Material Science, Vol. 4, p. 146 - 152.

Dekker L. [a.o.] Building Symbolic Information for 3D Human Body Modelling from Range Data [Article] // Proceedings of the Second International Conference on 3-D Digital Imaging and Modelling. - Ottawa, Canada: [no title], October, 1999 - IEEE Computer Society, p. 388 - 397.

Devroye L., Mucke E. P. and Binhai Zhu A Note on Point Location in Delaunay Triangulations of Random Points [Magazine] // Algorithmica (22) - Springer-Verlag New York Inc, 1998. - p. 477 – 482.

Digimask Ltd [Live], Face modelling software hybrid technology from images., www.digimask.com.

DOI Generating unified model for dressed virtual humans [Report]. - [no publ. ind.] : Visual Comput, 2005, p. 522 - 531. - DOI 10.1007/s00371-005-0339-6.

E Measurement Solutions Ltd Elektroniskā mērlente/ Electronic measuring tape [Live]. - E Tape. - www.e-tape.co.uk. - England.

Fan J. Yu W., Hunter L. Clothing appearance and fit: Science and technology [Book]. - Cambridge, England: Woodhead Publishing Limited, 2004. - p. 240. - ISBN 0-8493-2594-3.

FashionCad CAD/CAM [Live] // Clothing designing. - Cad Cam Solutions Australia Pty. Ltd. - www.fashioncad.net.

FitMe.Com Inc. [Live]. - Size Genie 3D software. - www.fitme.com. - USA.

Gemini CAD/CAM [Live] // Clothing designing. - Contact person for distributors: Mr. Traian LUCA. - www.geminicad.com.

Gerber CAD/CAM [Live] // Clothing designing, founder - Joseph Gerber. - www.gerbertechnology.com.

GFai Gesellschaft zur Forderung angewandter Informatik e.V. [Live]. - Full body scanner hybrid technology stripes projection and silhouette extraction. - www.gfai.de.

Gomes Abel J.P. [a.o.] Implicit Curves and Surfaces: Mathematics, Data Structures and Algorithms [Book]. - [no publ. ind.] : Springer-Verlag London Limited, 2009. - p. 351. - ISBN 978-1-84882-405-8; DOI 10.1007/978-1-84882-406-5.

Grafis CAD/CAM [Live] // Clothing designing. - Partner authorised to represent: Dr. Kerstin Friedrich, Responsible for the content of this site: Volker Friedrich. – June 2009. - www.grafis.de.

Grazia CAD/CAM [Live] // Clothing designing. - Руководитель разработчиков: кандидат физико-математических наук Виталий Ещенко. - www.saprgrazia.com.

Hamamatsu Photonics K.K. [Live]. - Hamamatsu bodyline full body laser scanning. - http://www.hamamatsu.com.

Hamano Engineering Co. Ltd. [Live]. - Hamano laser scanning technology. - www.voxelan.co.jp.

Hannelore Eberle, Hermann Hermeling un Hornberger Marianne, et.al. Clothing Technology [Book] / red. Roland Kilgus. - Wuppertal, Germany: Verlag Europa-Lehrmittel, 1999, 2nd English Edition, p. 256. - ISBN 3-8085-6222-6.

Hoechstmass Balzer GmbH Elektroniskā mērlente/ Electronic measuring tape [Live], www.hoechstmass.com. - Germany.

Hsueh Wen-Jean un Antonsson Erik K. Automatic high-resolution optoelectronic photogrammetric 3D surface geometry acquisition system [Article] // Machine Vision and Applications. - [no publ. ind.] : Springer Verlag Group, 1997, 10:98 – 113, p. 98 - 113.

Human Solutions GmbH [Live]. - 3D human body measurement software. - www.human-solutions.com. - Germany.

Hwang Su-Jeong Three dimensional body scanning systems with potential for use in the apparel industry [Article]. - Raleigh : [no title], 2001. - p. 63.

InSpeck Inc. [Live]. - 3D Capturor human body stripes projection scanning, www.inspeck.com, Canada.

Intellifit Corporation [Live]. - Cilvēka ķermeņa skenēšana ar elektromagnētisko viļņu metodi/ Scanning the human body with the electromagnetic wave method, www.corp.intellifit.com.

InvenTex CAD/CAM [Live] // Clothing designing, developed & manufactured by SEMACO company, 2009, www.inventex.eu.

ISPRS International Society for Photogrammetry and Remote Sensing [Live], 2009 – January 23, 2010, www.isprs.org.

Istook Cynthia L. Hwang Su-Jeong 3D body scanning systems with application to the apparel industry [Article] // Journal of Fashion Marketing and Management. - [no publ. ind.]: Henry Stewart Publications 1361-2026, 2001, Vol. II, p. 120 - 132.

Jindex CAD [Live] // Apģērbu projektēšana/ Clothing designing, Hong Kong Jindex Stock Co. Limted, www.jindex.net.

Kaļinka Māris: Arhitektūras telpiskās dokumentēšanas tehnoloģija/ Spatial architecture recording technology [Report]: Doctoral thesis/ Geomathics department; RTU BF Transport building institute, Riga, Riga Technical University, 2008, p. 127. - RTU ZB 992693.

Kang Tae Jin and Kim Sung Min Optimized garment pattern generation based on three-dimensional anthropometric measurement [Magazine] // International Journal of Clothing Science and Technology. - 0955-6222: MCB University Press Ltd, 2000 - 4, Vol. 12, p. 240 - 254. - ISSN: 0955-6222.

Krieviņš Ivars Tērpzinību antropoloģiskie pamati/Apģērbu antropometriskie parametri // Anthropologic Basics of Garment Studies/ Anthropometric Parameters of Clothing [Book]. - Riga: RTU Clothing and Textile Technology Department, 2003, Vol. Lecture summaries/ Instructions on the execution of laboratory work and self-dependent work, p. 62. - RTU ZB 0705011636[7].

Lectra CAD/CAM [Live] // Apģērbu projektēšana/ Clothing designing. - Publishing Director: Daniel HARARI. - 2009. - www.lectra.com.

Lectra Ltd. Kaledo Style or Kaledo Collection? [Report]. - France : Lectra Ltd., June 2009. - p. 7. - MS PowerPoint presentation.

Leko CAD/CAM [Live] // Apģērbu projektēšana/ Clothing designing. - Vilar Soft. - www.latelye.ru.

Letonika [Live]. - © Latvijas Zinātņu akadēmijas Terminoloģijas komisijas Informācijas tehnoloģijas un telekomunikācijas terminoloģijas apakškomisija/ © Information Technology and Telecommunication Terminology subcommision of the Latvian Science Academy Terminology commission; © Tilde, 2009, © EuroTermBank Consortium. - 2009. - http://www.letonika.lv.

Luhmann T, Robson S and S. Kyle, I., Harley Close Range Photogrammetry. Principles, Methods and Applications. [Book]. - Scotland, UK: Whittles Publishing, 2006. - p. 510. - ISBN 1-870325-50-8.

LVS EN ISO 15536-1 Latvijas Standarts; Ergonomika. Datormanekeni un ķermeņa maketi. 1.daļa: Vispārīgās prasības./Ergonomics-Computer manikins and body templates - Part 1: General requirements. [Report]. - Brussels: CEN - European Committee for Standardization, 2005. - ISO 15536-1:2005.

LVS EN ISO 15536-2 Latvijas Standarts Ergonomika. Datormanekeni un ķermeņa maketi. 2.daļa: Kompjūtermanekenu sistēmu funkciju verifikācija un izmēru validācija./Ergonomics-Computer manikins and body templates - Part2: Verification of functions and validation of dimensions for computer manikin sist. [Report]. - Brussels : CEN - European Committee for Standardization, 2007. - ISO 15536-2:2007.

LVS EN ISO 20685 Latvijas Standarts 3D skenēšanas metodoloģijas starptautiski saderīgām antropometrisko datu bāzēm/ 3D scanning methodologies for internationally compatible anthropometric databases [Report]. - Brussels: CEN - European Committee for Standardization, 2005. - ISO 20685:2005.

LVS EN ISO 7250 Latvijas Standarts Cilvēka ķermeņa pamatizmēri tehniskiem projektiem/ Basic human body measurements for technological design [Report]. - Brussels: CEN - European Committee for Standardization, 1997.

Magnenat-Thalmann Nadia Where Research Means Creativity [Live] // MIRALab. - University of Geneva, October 2007. - www.miralab.unige.ch.

NovoCut CAD/CAM [Live] // Apģērbu projektēšana/ Clothing designing. - Authorized representative: Mrs Annette Krumpa. - www.novocadcam.de.

OptiTex CAD/CAM [Live] // Apģērbu projektēšana, imitācija/ Clothing designing and imitation. - President and CEO - Ran Machtinger. - www.optitex.com.

PadSystem CAD/CAM [Live] // Apģērbu projektēšana, imitācija/ Clothing designing and imitation. - PAD System International Limited. - www.padsystem.com.

PNNL [Live]. - Department of Energy's Pacific Northwest National Laboratory. - http://www.pnl.gov/.

Protopsaltou Dimitris [a.o.] A body and garment creation method for an Internet based virtual fitting room [Report]. - Geneva: MIRALab CUI, University of Geneva, 2007. - CH-1211, Switzerland, p. 17.

Razdomahins Nikolajs, Viļumsone Ausma and Dāboliņa Inga CAD OF THE CLOTHING INDUSTRY [Article] // RTU Scientific article corpus. - Riga : [no title], 2007. – Textile and Clothing Technology – part 9: Material Science, Vol. 2. - p. 111 - 116.

RichPeace CAD/CAM [Live] // Apģērbu projektēšana/ Clothing desinging. - Richpeace Group Co., Limited. - www.richpeace.com.

Rupp Martin un Kirchdörfer Elfriede Possibilities and capabilities of 3D-body-scanning systems for the purpose of risk assessment [Report]. - Germany : Bekleidungsphysiologisches Institut Hohenstein, Department of Clothing Technology, 2005. - p. 23. - HETRA RfP C1.6 Human Health Projects - Consumer Exposure.

Sanyo Electric Co. ltd [Live]. - Hibrīdsistēma 3D skenēšanai izmantojot silueta nolasīšanu un kodētas gaismas projekciju/ Hybrid System for 3D Scanning Using Silhouette Readings and Coded Light Projection. - www.sanyo.co.jp; www.pierimo.net.

Sayem Abu Sadat Muhammad 3D Design of Garments [Report]. - UK: University of Manchester, Department of Textiles, 2009. - Submitted to IMB Innovation Award 2009.

Scharrenbroich Christine Mehr Brust, Mehr Taille, Mehr Hüfte [Article] // FRANKFURTER ALLGEMEINE ZEITUNG. - 2009. Part 9, Vol. 93.

Siegmund Jana [a.o.] Development of parametric virtual dummies; 3D patterning of corsetry [Magazine] // Textile Network. - Dresden: apparel, 2007, 7 - 8. - TU Dresden.

Simmons Karla, Istook Cynthia L. un Devarajan Priya Female Figure Identification Technique (FFIT) for Apparel Part1: Describing Female Shapes [Article] // Journal of Textile and Apparel Technology and Management. – 2004, 4. Vol. I. p. 16.

Singular Inversions FaceGen [Live]. - Face modeller software hybrid image technology. - www.facegen.com.

Staprim CAD/CAM [Live] // Apģērbu projektēšana/ Clothing Designing. - founder&developer Раздомахин Н.Н. - www.staprim.com.

Sungmin Kim and Chang Kyu Park Basic garment pattern generation using geometric modelling method [Magazine]. - South Korea: Emerald Group Publishing Limited, 2007. - Vol. 19. No.1. p. 7 - 17. - DOI 10.1108/09556220710717017.

Sýkora Stanislav Approximations of Ellipse Perimeters and of the Complete Elliptic Integral E(x). Review of known formulae [Report]. - Castano Primo, Italy: Stan's Library, 2005. - DOI: 10.3247/SL1Math05.004 .

Szabó Orsolya Nagy un Tamás Péter SYLVIE® 3D SYSTEM USING FOR SKIRT AND TROUSERS CONSTRUCTIONS [Report]. - Biela,Italy : Autex 2008, 2008. p. 7.

TanyaGeo CAD/CAM [Live] // Apģērbu projektēšana/ Clothing designing. - Tanya Geometrik Pvt. Ltd. - www.tanyageo.com.

Telmat Industries [Live]. - Symcad full body scanner stripes projection technology. - www.telmat.com, www.symcad.com. - France.

Vanags Valdis Fotogrammetrija/ Photogrammetry [Book]. - [no publ. ind.] : LR Valsts zemes dienests, 2003. - p. 275. - ISBN10: 9984950891; ISBN13: 9789984950891 .

Viļumsone Ausma Adaptējamas automatizētas apģērbu konstruēšanas sistēmas struktūras un algoritmu izstrāde/ Development of a structure and algorithms of an adaptable computer aided apparel designing system [Report] : Doctoral thesis/ Engineering sciences, Textile Technologies and Machines. - Riga: RTU, 1993. p. 129. - Monogr.ier.Nr.000198748.

Viļumsone Ausma and Dāboliņa Inga The Estimation and Approbation of 3D Garment Designing and Photo Measurement Method [Article] // 4th INTERNATIONAL TEXTILE, CLOTHING & DESIGN CONFERENCE - Magic World of Textiles. - [no publ. ind.] : Faculty of Textile Technology, University of Zagreb, Zagreb, Croatia, October 2008 - Book of proceedings of the 4rd INTERNATIONAL TEXTILE, CLOTHING & DESIGN CONFERENCE – Magic World of Textiles. - p. 676 - 681.

Viļumsone Ausma and Dāboliņa Inga The Possibilities of Garment 3D Designing [Conference] // XI International Izmir Textile and Apparel Symposium. - Izmir: Ege University Textile Engineering Department, Year 2007. - p. 161 - 170. - Proceedings.

VisImage Systems Inc. [Live]. - Human body measurement silhouette extraction technology. - www.vis.ca.

Vitronic Stein Bildverarbeitungssysteme GmbH [Live] // Vitus laser scanning technology. - http://www.vitronic.de/. - Germany.

Wen Z. [a.o.] Delaunay triangulation with partial least squares projection to latent structures: a model for G-protein coupled receptors classification and fast structure recognition [Magazine] // Amino Acids (2007) 32. - 2007. - DOI 10.1007/s00726-.

Wicks and Wilson Limited [Live]. - Wicks and Wilson human body scanning stripes projection technology. - www.wwl.co.uk. - England.

WildGinger CAD/CAM [Live] // Apģērbu projektēšana/ Clothing designing. - President - Dr. Lisa Shanley. - www.wildginger.com.

Winsborough Stuart An Insight into the Design, Manufacture and Practical Use of a 3D Body Scanning System [Report]. - England : Wicks and Wilson Limited, 2006. – p. 11.

Winsborough Stuart Towards Photo-realistic 3D Image Capture [Report]. - England: Wicks and Wilson Limited, 2001. - Scanning 2001 – TriForm, p. 18.

Xu B. [a.o.] Three-dimensional body scanning system for apparel mass-customization [Magazine]. - [no publ. ind.] : The University of Texas at Austin Department of Human Ecology Optic Engineering, 2002. - 41(7). - p. 1475 - 1479.

XX Production online GmbH [Live]. - Hardware and software solutions for body scanning hybrid technology laser spot and 5 manual measurements. - www.xxpo.de; www.bodyscanningcrm.com.

Yan He and Fiorito Susan S. CAD/CAM diffusion and infusion in the US apparel industry [Magazine] // Journal of Fashion Marketing and Management. - USA: Emerald Group Publishing Limited 1361-2026, 2007. - 2: Vol. 11. - p. 238 - 245. DOI 10.1108/13612020710751400.

Youngsook Cho [a.o.] An interactive body model for individual pattern making [Article] // Emerald International Journal of Clothing Science and Technology. - 2005 – II, Vol. 17. - p. 91 - 99.

Бескоровайная Г.П. Конструирование одежды для индивидуального потребителя [Book]. - Moscow: ACADEMIA, 2004 - 2. p. 120. - ISBN 5-7695-1873-1.

Гуревич М. М. and Сапожников Р. А Введение в фотометрию 1968. and Теоретическая фотометрия 1967 [Book chapter] // Большая Советская Энциклопедия. - 1978.

Дунаевская Т.Н. [a.o.] Основы прикладной антропологии и биомеханики [Book] / red. Коблякова Е.В.. - Moscow: Информационно-издательский центр МГУДТ, 2005. p. 280 - ISBN 5-87055-069-6 УДК[572:687](01) ББК19.8-30.3.

Куршакова Ю.С. [a.o.] Размерная типология населения стран-членов СЭВ [Book]. - Moscow: publishing house "Легкая индустрия", 1974. - p. 440.

Коблякова Е.Б., Ивлева Г.С. and Романов В.Е. a.o. Конструирование одежды с элементами САПР [Book] = Учеб.для вузов. - Moscow: „Легкая промышленность и бытовое обслуживание", 1988 – Vol. 4. p. 464. - ISBN 5-7088-0239-1.

ОСТ-17-325-86 Изделия швейные, трикотажные, меховые. Типовые фигуры мужчин. [Report]. - Moscow: ЦНИИТЭИлегпром, 1986. - p. 74 .

ОСТ-17-326-81 Изделия швейные, трикотажные, меховые. Типовые фигуры женщин. [Report]. - Moscow: ЦНИИТЭИлегпром, 1981. - p. 109.

Павловская Виолетта Перспективное проектирование одежды с использованием САПР «COMTENSE» [Magazine] // Курьер. - Moscow: "Легкая промышленность", March 2009. - 4. - p. 9 - 10.

Раздомахин Н.Н. [a.o.] Особенности трехмерного проектирования женской одежды в системе СТАПРИМ для серийного и индивидуального производства" [Report]. – St. Petersburg: p. 133, 2003.

Раздомахин Н.Н. Система трехмерного автоматизированного проектирования в индустрии моды [Book]. - St. Petersburg: СТАПРИМ, 2006. - p. 134.

Стебельский М.В. Макетно-модельнный метод проектирования одежды [Book]. - Moscow: ЛЕГКАЯ ИНДУСТРИЯ, 1979. - p. 160. - ББК 37.24; С 79; УДК 687.01:572.7:528.7:7.01/02.

Сухарев М.И. and Бойцова А.М. Принципы инженерного проектирования одежды [Book]. - Moscow : издательство „Легкая и пищевая промышленность", 1981. - p. 272. - ББК 37.24; С 91; УДК 687.1.016.

ЦНИИШП Типовые фигуры женщин. Размерные признаки для проектирования одежды. [Report]. - Moscow : ОАО Центральный научно - исследовательский институт швейной промышленности, 2003.

ЦОТШЛ Единый метод конструирования женской одежды, изготавливаемой по индивидуальным заказам населения на фигуры различных типов телосложения. [Book]. - Moscow: ЦБНТИ, 1989. - Vol. part I.