7th International Conference and Exhibition on
3D Body Scanning Technologies
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Book of Abstracts

7th International Conference on 3D Body Scanning Technologies

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Hometrica Consulting - Dr. Nicola D'Apuzzo
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INTRODUCTION

Conference director's message #00

Nicola D'APUZZO
Hometrica Consulting, Ascona, Switzerland

The 7th International Conference and Exhibition on 3D Body Scanning Technologies (3DBST 2016) was held on November 30th to December 1st 2016 in Lugano, Switzerland.
The first six international conferences from 2010 to 2015 were all largely attended with 200-250 participants from different countries, different technical fields and different industries.
The rich technical programs of the six events included a wide variety of works related to applications, developments and research on 3D body scanning from all over the world.
The conferences were accompanied by parallel exhibitions featuring live demonstrations of 3D body scanning equipment and solutions. Various manufacturers had chosen our events for presenting and announcing world and international premieres.
The success of the sixth edition of 2015 with over 220 attendees confirmed again the 3DBST conference as the most important international event for the sectors related to 3D body scanning technologies. With the seventh conference and exhibition of 2016, we will continue the role as the world leading technical and scientific platform dedicated to these specific fields.
This book of abstract is divided in sections according to the conference's technical program and it includes the abstracts of the presentations and/or of the papers published in the proceedings of the conference. The corresponding papers (if available) can be easily found in the digital proceedings by the paper id number indicated in the table of contents and after each abstract's title.
Note: not all the presentations at the conference have a correspondent abstract.

TECHNICAL SESSION 1: MEDICAL SCANNING SYSTEMS

3D Imaging Systems of Canfield Scientific

Canfield Scientific Inc., Fairfield NJ, USA

Canfield Scientific is the leading developer of photographic imaging solutions for the medical and skin care industries. Product lines include Mirror imaging software, VISIA Complexion Analysis, VECTRA 3D Systems, Reveal facial imagers, VEOS dermatoscopes, IntelliStudio photographic studio and imaging systems for clinical photography.

Medical Grade 3D Full Body Scanners: Design and Experience

P. Aswendt, R. Höfling, M. Schatz
ViALUX Messtechnik + Bildverarbeitung GmbH, Chemnitz, Germany

The paper gives an overview on specific demands for medical scanning systems including both normative requirements and practical needs in clinics and health care facilities. The most recent ViALUX solution for medical grade 3D scanners is described. Measuring technology, hardware components, and software algorithms result from long-term developments. Leading-edge approaches in all 3 fields are necessary to build a high-performance solution that fulfils medical demands at affordable costs. Automation plays a key role for a reliable and operator independent scan result. Selected examples will demonstrate how the modular software architecture enable convenient graphical user interfaces for respective medical use cases of the ViALUX zSnapper® cart.

Manu3 - A Touch-less Portable Desktop Device to Measure the Dimensions of the Hand

Anatomi Metrix Inc., Montreal QC, Canada

Anatomi Metrix is focused on the development of technologies, devices and protocols dedicated to the anatomical measurements and evaluation of conditions of the human hand. Manu3 is a touch-less portable desktop device to measure the dimensions of the hand and fingers in terms of lengths and circumferences.

Chishine 3D Face and Body Scanning Systems

Xi’an Chishine Optoelectronics Technology Co. Ltd., Xi'an, China

Xi'an Chishine Optoelectronics Technology is an high-tech company focusing on 3D scanners, which has developed, with ultra-fast 3D scanning technology, fast body scanners and industrial 3D sensors. Chishine 3D scanners are widely used in the fields of medical plastic surgery, scientific experiments, industrial inspection and others.

TECHNICAL SESSION 2: BODY SCANNING FOR APPAREL I

Adapted Performance Sportswear #32

Alexandra DE RAEVE, Simona VASILE
Fashion & Textiles Innovation Lab, University College Ghent, Ghent, Belgium

Sportswear is based on sizing tables developed on a basis of average body sizes and will therefore not fit population groups with body proportions categorically different from average (e.g. athletes from different sport disciplines, disabled people or people with specific professions). This is not only detrimental for the aesthetics and comfort of the wearer but also in stark contrast with functionality (e.g. orthopedic products; sportswear meant to offer some support, to improve performance or to facilitate fast revalidation; some intelligent textiles for monitoring) and the changing demands of the consumers who lose their tolerance for regular products and have become more and more demanding for garments with a personalized fit. These groups of products require an optimal contact with the skin, they have to fit, otherwise they lose their functionality.

The overall objective of the project Adapted Performance Sportswear is to develop comfortable, fitted and functional (sports)wear for population groups with body shapes and proportions different from the average population. The aim of the project is to gain better insight in anthropometric differences (average population versus various groups of athletes) and work out a methodology for translating this information effectively to the garment production. The concept of compression, support and restriction of certain movements by employment of new and innovative elastic materials will be further explored in relation to the fit.

Improving Men's Underwear Design by 3D Body Scanning Technology #37

Victor E. KUZMICHEV1, Zhe CHENG2
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2 Institute of Clothing, Wuhan Textile University, Wuhan, Hubei, P.R. China

This research devoted to the scanning technology of improving an underwear design by means of studying male bodies morphology. Increasing demands of contemporary men about an underwear have affected the way of designing including the choosing of structure, construction, knitted materials in accordance with the body morphology, perception, possible body reshaping, etc. It requires a combination of traditional design approaches with new data base. Traditional approach used limited number of body sizes and some empirical values, but this simple data base is not fully to reflect the male bodies morphology if the fit, comfort and additional functionalities of products should be reduced. Our exploration takes into attention the opinions and demands of more than 300 young people (Chinese, Russian, Indian). The underwear they have bought most appeared the size and front crotch discomfort; moreover, the majority of respondents said, simple way of underwear sizing (such as S, M, L, XL, XXL…) doesn't give them good choice during buying underwear. So, the traditional basic body sizes for underwear design are outdated and unreasonable, it should be readjusted and reformed. We used the body scaner Vitus Smart XXL to create new data base for underwear design.

The Impact of the Outer Layers in Multi-Layer Clothing Systems on the Distribution of the Air Gap Thickness and Contact Area #45

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1 Laboratory for Protection and Physiology, Empa – Swiss Federal Laboratories for Materials Science and Technology, St. Gallen, Switzerland;
2 Institute of Textile Technology and Process Engineering (ITV), Denkendorf, Germany

The heat and mass transfer in clothing, and hence its thermal comfort, do not only depend on the properties of fabric but also on the variation of the thickness of air layers and the magnitude of the contact area. The garment design and the body geometry have major influence on the above-mentioned parameters. Until now several studies have been conducted to analyse the impact of clothing fit at lower and upper body, moisture content and body shape and posture on the distribution of the air within garment. The present study addressed the effect of adding on a second layer to the clothing system on the air gap thickness and the contact area.

For this reason, the distribution of the air gap thickness and contact area for the upper body dressed with regular- or loose-fitted inner layer and the regular-fitted jacket was experimentally determined. The outer layer of the 2-layer clothing system was made out of transparent foil. The foil was chosen to ensure high stability, good transparency, least reflection and similar stiffness to typical jacket fabrics. The 3D scanner was able to scan through the outer layer in a smooth process and capture the shape of the inner layer underneath. Each inner layer garment and a combination of inner and outer layer garments was subjected to 3D scanning and analysis of air gap thickness and contact area by imposing 3D scans of the nude and dressed manikin and advanced post-processing in dedicated software. Finally, the results for the inner layer with and without outer layer were compared.

The air gap thickness and the contact area varied with different fit levels corresponding to the ease allowance, which was in agreement with other studies in the literature. The contact area increased and air gap thickness decreased, when the foil jacket compressed the inner layer in both fits. However, as soon as the ease allowances of the inner and outer layers were similar, the compressing effect of the outer layer disappeared. The findings can be used to optimize the fit and comfort of garments.

Towards Developing a Method for Identifying Static Compression Levels of Seamless Sports Bras using 3D Body Scanning #46

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Iowa State University, Department of Apparel, Events and Hospitality Management, Ames IA, USA

Sports bras are functional garments designed to minimize breast movements, while providing support, during physical activity. Understanding the factors influencing breast support is necessary for future development of better functioning sports bras to prevent wearers from soreness and pain. Compression was found to be the most effective factor in controlling the breast support. Moreover, respiratory state was reported to be significantly affecting bra size and comfort. Therefore, our pilot study explored how females' breast area measurements change when wearing seamless sports bras of different support levels. Two medium-size seamless sports bras with low and medium compression (i.e. breast support) levels were tested with and without removable pads. A [TC]^2 NX-16 three-dimensional (3D) body scanner was used to scan three females, with three different cup sizes, with and without wearing bras. Additionally, for each condition participants were scanned at fully inhaled and relaxed (neutral) positions. In order to identify compression rate changes among various conditions, twenty-one slice measurements taken at 0.25 inches intervals between under bust and armpit levels were collected and compared. The compression rates for each slice level were calculated by subtracting the slice circumference from the no bra circumference, and dividing the result by the no bra measurement. Our preliminary findings showed that the highest compression rates were achieved without pads, in both relaxed (5.06%) and inhale conditions (4.73%), at levels below bust height. Cumulative compression rates over all levels also showed higher compression rates for the bras without pads. Visual analyses revealed smoother contour lines and a more uniform distribution of compression all around the body for the medium support bra as compared to the low support bra for both with and without pads conditions.

TECHNICAL SESSION 3: Body Scanning for Health, Fitness, Sport

New Tools for Body Image Analysis: A Modern Framework Using 3D Body Scanning #22

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Background. Body Image Analysis (BIA) is an important area of research. It attempts to assess how the subject perceives their physical appearance, which can often differ substantially with the actual appearance of their body. One practical application is its use in qualifying bariatric patients prior to undertaking a weight loss surgery procedure. The psychologist plays as important a part in approving the weight loss surgery as the surgeon. The psychologist must undercover disorders such as binge eating and other behavioral distortions that may jeopardize successful surgical results or complicate surgical recovery. The tools used for BIA were developed in the 1970s and early 1980s.and have remained relatively stagnant. This paper discusses replacing the traditional 2D paper diagrams in use today with realistic 3D body scanning images. It also provides architectural framework options to incorporate and expand the use of a 3D body scanner within a weight loss surgery clinic or conduct BIA within a cloud based environment.

Existing Methods. Currently, the individual is given a drawing with a series of 9 gender specific figures. These figures range from very thin to progressively overweight. Each figure has a number associated with it and the outlines of the figures are very generic. The individual is asked to select which one of the nine figures they believe most closely resembles the present image of themselves. Further, they are asked which of the images they would most like to resemble 1 year after weight loss surgery. Finally, they are then asked which one of the images they would be satisfied with as a maintainable long term goal. These questions attempt to objectify cognition of present body appearance. They also attempt to uncover expectations of the weight loss surgery result. This process can be immensely improved by using 3D body scanning technology, personalized images and computerized scoring techniques.

Updated Methods. 3D body scanning is poised to replace the traditional paper body image figures. The existing figures outline a single female of gynecoid shape or male of android shape from slender to grossly overweight. The individual is asked to associate the perception of their particular shape and size within a set of images that may in no way resemble their own physical shape. This is replaced by a normalized set of 3D

images based on statistical shape categorizations. The individual identifies with this “top-level” shape, selects the shape and a series of numbered volumetric scaled images then appears. This selection is registered and the individual’s pre-operative 3D body scan is then displayed next to it. This allows cognitive recognition between the actual and perceived body image. The desired post-operative body image goal and the post-operative satisfaction image are stored. All assessment questions are collected via computerized program, and successive post-operative scans are used for iterative satisfaction updates.
Discussion. There are two architectures to be discussed. One architecture presumes that a 3D body scanner is on premise. In this case, individuals undergoing BIA testing can use personalized scan information in near real time. The other architecture to be outlined bypasses the need for an in-clinic body scanner. Instead, this architecture is cloud based and relies on statistical models generated from thousands of 3D body scans. In this case height, weight and certain circumferential measurements are used to look up or generate the 3D body image. Regardless of which architecture is used, there is a vast improvement in body model realism, data collection and data analysis capability.

Changes in the Volume and Circumference of the Torso, Leg and Arm after Cycling in the Heat Determined Using 3D Whole Body Scanners #09

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Whole body volume changes due to sweat loss after exercise in the heat are well documented, but little is known about the relative contribution of the torso and extremities to these volume changes. It is the purpose of this study to quantify these effects. Therefore, seven healthy male subjects were scanned using a SizeStream and Vitronic whole body scanner prior to and shortly after they lost 1.7 ± 0.1% of their body weight due to cycling at 2 W/kg in a 35°C, 20% relative humidity climatic chamber for 75 minutes. Whole body volume loss was 1.0 ± 0.7% using the SizeStream scanner and 1.3 ± 0.6% using the Vitronic scanner. Torso volume decreased most with 2.1 ± 1.5% ($p=0.009$) and 5.6 ± 3.1% ($p=0.002$) followed by the legs with 1.1 ± 2.7% (N.S.) and 2.9 ± 1.0% ($p<0.0001$) for SizeStream and Vitronic respectively. Changes in arm volume were negligible. The circumference decreased significantly for the chest and upper legs but not for the waist and arms. We conclude that the major part of sweat loss originates from the torso and legs, but since both scanners did not produce similar results likely due to differences in accuracy, we recommend using high-resolution scanners to record volume changes in more detail.

Analysis of Body Mass Components in Soccer Players Aged 14 to 17 Years in Republic of Macedonia

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Institute for ME Physiology and Anthropology, Medical Faculty, Ss. Cyril and Methodius University (UKIM), Skopje, R. Macedonia

The aim of the study was to present body composition parameters of young male soccer players and to show the differences in respected age groups. A total of 80 male soccer players were divided into two groups according to the age: younger- 14 to 15 years; older- 16 to 17 years. The estimation of three body mass components: the muscular component (MM kg and MM%), the bone component (BCkg and BC%) and the body fat (BFkg and BF%) showed that in the whole group body mass of young soccer players were separated in MM=34.25kg; MM%=51,67%; BC=11,8kg; BC%=18,04%; BF=10,31kg; BF%=15,5%. Subgroup aged 14-15 years have shown: MM= 29,8kg; MM%= 49,64%; BC=10,6kg; BC%=18,37%; BF=8,96kg; BF %=15,04%. The older subgroup (16-17 years) have shown the body components as: MM= 36,16kg; MM %=52,42%; BC=12,29kg; BC%=17,91%; BF=10,81kg; BF%=15,67%. The acquired data could be used as standard values for Macedonian young soccer players. We observed small but significant differences between two subgroups; younger soccer players had higher value for bone component, but smaller muscular and fat component than older subgroup.

TECHNICAL SESSION 4: Body Scanning Systems I

FARO’s 3D Scanning Solutions

FARO Swiss Holding GmbH, Beringen, Switzerland

FARO's product line-up offers a variety of cutting-edge 3D measurement solutions, including measuring arms, laser trackers, 3D laser scanners, 3D hand-held scanners, 3D imagers and software solutions. FARO serves over 20 different industries and a wide range of applications, including 3D body scanning.

VITRONIC's 3D Body Scanning Systems
VITRONIC Dr.-Ing. Stein Bildverarbietungssysteme GmbH, Wiesbaden, Germany
With 20 years of experience in the field of body scanning, VITRONIC is among the pioneers of fast, automatic 3D measuring of the human body. VITUS body scanners are used around the world for customized clothing, standardization, ergonomics, orthopedics, sports medicine, and printing of 3D figurines.

Dagubert - A Fully Automated and Self-Operated 3D Photo Studio
3D Elements GmbH, Innsbruck, Austria
3D Elements builds Dagubert, a fully automated and self-operated 3D photo studio. Due to its latest IR projection technology and its scalable system, it creates the best 3D data quality. Dagubert can be used by anyone anywhere, at events, festival or outdoor. The integrated info screen and a sound system explain the process to the customer. The electronic payment system completes the self-service concept of Dagubert.

The botscan 3D Full Body Scanner
botspot GmbH, Berlin, Germany
botspot produces and develops lighning-fast scanning-technology. The botscan 3D full body scanner generates pin-sharp scans and depicts even the tiniest details in the shortest time of less than 1/100th of a second. The modular construction of the scanner allows its adaption to any size, need and application.

TECHNICAL SESSION 5: Medical Applications I

A Mobile, Multi Camera Setup for 3D Full Body Imaging in Combination with Post-Mortem Computed Tomography Procedures #30
Sören KOTTNER1, Lars C. EBERT1, Garyfalia AMPANOZI1,
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2 Forensic Science Institute, Zurich, Switzerland
Three dimensional (3D) models of deceased and injured people in combination with 3D scans of injury causing objects can assist forensic investigations in reconstructing event scenes. Medical imaging techniques, such as post-mortem computed tomography (PMCT) and post-mortem magnetic resonance imaging (PMMR), have been successfully applied to forensic investigations and can add beneficial value to standard autopsy examinations. These imaging modalities can be helpful for 3D reconstructions, especially when internal findings, such as bone fractures, organ damage and internal bleeding, are relevant for the investigation. However, none of these techniques can adequately visualize pattern injuries, such as boot prints and bite marks, or any type of blunt force trauma that forms distinct discolorations on the body's surface. This is why 3D surface imaging techniques have been introduced to the forensic community. Unfortunately, many commercially available optical scanning systems are cost intensive, time consuming and can only be applied before or after a CT scan has been performed. In this article, we present a mobile, multi-camera rig based on close-range photogrammetry that is inexpensive, fast in acquisition time and can be combined with automated CT scanning protocols. The multi-camera setup comprises seven digital single-lens reflex (DSLR) cameras that are mounted on a mobile frame. Each camera is equipped with a remote control that can trigger the shutter release of all cameras simultaneously. In combination with a medical CT scanner, image acquisition of the multi camera setup can be included into an automated CT scanning procedure. In our preliminary study, textured 3D models of one side of the body were created in less than 15 minutes. The photo acquisition time combined with the modified CT scanning protocols lasted 3:34 minutes whereas the subsequent computation of a textured 3D model based on a low resolution mesh lasted 10:55 minutes. The mobile, multi-camera setup can also be used manually in combination with examination couches, lifting carts and autopsy tables. Finally, the system is not limited to post-mortem investigations but can also be applied to living people and may be used in clinical settings.

3D Scanning for Hand Orthotic Applications: A Comparative Assessment between Static and Real-Time Solutions #52
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2 Università degli Studi di Brescia, Dip. di Ingegneria Meccanica e Industriale, Brescia, Italy
The personalization of medical devices has made considerable progress in recent years. In the orthopedic field, following a typical reverse engineering approach, 3D scanning of anatomical regions of interest is the starting point for various kind of customized manufacturing, followed by the design of the device and its fabrication, particularly with additive manufacturing techniques. In this context, particularly challenging issues emerge from the customization of hand orthotic devices. The present work focuses on the identification and

comparison of suitable scanning procedures in order to acquire accurate hand and fingers 3D models. Two different types of structured light scanners (static and real-time) were compared and several configuration of the hand were studied and acquired, allowing to evidence strength and weakness of the various approaches, while keeping in consideration the target application. In particular, the issues related to the presence of involuntary movements during acquisition are considered and possible solving approaches indicated.

Foot Abnormality Mapping using Statistical Shape Modelling #47

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1 iMinds – Vision Lab, Dept. of Physics, University of Antwerp, Belgium;
2 RSscan International NV, Paal, Belgium

About 20% of the population suffer from disabling foot or ankle pain that require the use of foot orthotics. Traditionally, those foot orthotics are designed manually, but digital procedures are desired to provide a faster, more objective, and more reliable workflow. In this study, we introduce a method for detecting shape abnormalities in feet for the purposes of pathology diagnosis and orthotic design. The proposed method consists of two phases. In the training phase, a statistical 3D foot model (based on 42 healthy subjects) is built. In the test phase, the landmarks of a new 3D foot scan are compared to the trained model. A landmark is detected as an outlier if it is in the extreme ranges. This testing process is repeated at all landmarks to identify all abnormal foot regions. Preliminary results show that, when testing a foot of a known pathology (hallux valgus, heel spur, foot pronation), we are able to detect abnormal regions accurately. We also examined the effect of using rigid or similarity-based alignment during 3D model building and abnormality detection. We show that our proposed method is a faster and a more objective approach than traditional approaches for abnormality detection of the foot. As such, this method may prove useful in the medical diagnosis of foot pathologies and in automated orthotic design.

Laser Scanner Versus Stereophotogrammetry:
A Three-Dimensional Quantitative Approach for Morphological Analysis of Pubic Symphysis #18

Valentina PUCCIARELLI1, Daniele Maria GIBELLI1,2, Marina CODARI1,
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2 LABANOF, Laboratorio di Antropologia e Odontologia Forense, Dipartimento di Science Biomediche per la Salute, Università degli Studi di Milano, Milano, Italy

The reconstruction of biological profile is a crucial step for personal identification of unknown decedents, both in forensic and archaeological context. At this purpose, determination of age at death is a very important issue. Among the skeletal regions used for estimating it, the analysis of pubic symphysis by Suchey-Brooks method remains the most reliable aging technique. In the last years, technologies involving 3D image acquisition have acquired a growing importance in anthropology and may provide a relevant help in diffusion and sharing of skeletal specimens. In particular, among all the new available instruments, laser scanners and stereophotogrammetric systems are particularly useful to obtain 3D reconstructions of the pubic symphyseal surface. Furthermore, the possibility to create digital models of these bony structures allows researchers to easily and fast share their datasets worldwide, avoiding any possible damage to the real sample. This study aims at verifying the technical reproducibility of 3D acquisitions, performed by laser scanner and stereophotogrammetry, as a preliminary study to possible assessment of differences in age at death estimation. Since accuracy and reproducibility of these two instruments have already been evaluated, the study aims at comparing them in order to verify if there are some differences on relevant measurements obtained from the analysis of the 24 commercial casts (by Diane France). These 24 symphyseal casts (12 female and 12 male) were scanned by a dental laser scanner (Dental Wings series 3, Dental Wings Inc., Montreal, Canada) and a stereophotogrammetric system (Vectra 3D, Canfield Scientific, Fairfield, NJ). For each sample two scans were performed by the same tool and some measurements (symphyseal surface length, symphyseal surface area and billowing area) were taken twice on digitized surfaces, by the same operator. The second assessment was performed 15 days after the first one.
Repeatability of operator measurements on different scans was assessed by paired Student t-test, or Mann-Whitney test, depending on data distribution. Linear regression was performed as well. To compare the two instruments, Bland-Altman analysis was carried out for billowing measurements. Results show no significant difference ($p>0.05$) in identification of the same parameter on different scans through both instruments and no significant difference between billowing areas, measured through laser scanner or stereophotogrammetry. In conclusion, data suggest that both 3D image acquisition systems may provide a technically reliable reproduction of pubic symphysis. However, the technical reproduction of skeletal specimens does not mean

that the 3D scans are suitable for age estimation, which remains, in anthropological practice, a morphological procedure and requires a specific experience of the operator. Further studies are required to validate the opportunity to use this approach for anthropological age at death estimation.

Application of 3D Scanning in Prosthetic & Orthotic Clinical Practice #36
Jiri ROSICKY1,2,3, Ales GRYGAR1,2, Petr CHAPCAK1,2, Tomas BOUMA1,2, Jan ROSICKY1,2
1 Invent Medical Group s.r.o., Ostrava, Czech Republic;
2 ING corporation s.r.o., Frydlant nad Ostravici, Czech Republic;
3 Ortopedicka protetika Frydek-Mistek s.r.o., Frydek-Mistek, Czech Republic
This presentation is focused on application of 3D body scanning that represents a standard part of digital processes that we use in our prosthetic & orthotic clinical practice. The description of digital workflows such as CAD/CAM process (3D scanning, CAD/CAM, CNC milling) or Direct Digital Manufacturing process (3D scanning, computational modelling, 3D printing) will be done. We will give an overview of the application of different scanners for P&O clinical practice.

TECHNICAL SESSION 6: Body Scanning Systems II

Size Stream's 3D Body Scanning Solutions: from Handheld Tablets to Retail Booths
Size Stream LLC, Cary NC, USA
Size Stream is focused on 3D color body scanning, 4D scanning and all related applications requiring high performance, high automation and cost effective solutions. Size Stream products are widely used for research, size prediction and custom fit specification of clothing, body measurement for health and fitness applications and color 3D printing applications.

Styku: Innovative 3D Body Scanner
Styku, Los Angeles CA, USA
Styku is an innovative 3D body scanner that captures a person's true shape, renders an exact 3D model of that shape and extracts hundreds of precise body measurements within seconds using the world's most powerful 3D camera. Styku's digital technology has been proven to increase ROI in a range of industries including fitness, wellness, and fashion. A truly unique and effective way to extract body data.

Bodyscanning as an Enabler for Digital Fashion Process
Peter BERNINGER, Anton PREISS, Andreas SEIDL
Human Solutions GmbH, Kaiserslautern, Germany
Fashion has become a very fast business during the last few years: Many companies offer up to 12 collections a year. The digitization of worksteps is a key to success, one which streamlines the production process where it is possible. But digitization should not only make the fashion industry work faster. It should also enable companies to create better products for their customers – products, that fit perfectly and prove, that someone knows his target groups.
Technical solutions are available for the whole fashion process, from the very first idea to the sale of the finished product. But putting the human being in the centre of all considerations is an unique approach.
Three theses, why 3D-Bodyscanning should play a key role in the fashion process:
1) It offers knowledge of the market: 3D-Bodyscanning is mandatory to gain reliable and comparable information about the body measurements, the shape of the human being and country specific differences. Human Solutions has realized size surveys in different countries to show and prove diversity – for fashion makers, these information are essential when it comes to the fitting process.
2) It distinguishes different target groups: Statistical avatars based on the size surveys help to fasten the design process to increase the fit rate, to improve the customer's satisfaction and to be more successful. Therefore, the digitization of the customer is the base for 3D product development.
3) It reveals how client and product rely on each other: For the fashion industry, digitization will not only change the way of how fashion is developed and produced, but also how it is communicated and presented to the customer. 3D-Bodyscanning is a tool to include an individual into the fashion process.

Temporal 3D Body Surface Imaging (4D) to Support Product Innovation in Wearable Technologies
Chris LANE
3dMD Ltd., London, UK
3dMD, a proven leader in 3D high-precision anatomical scanning, will be demonstrating workflow efficiencies with its latest temporal-3D (4D) capture systems. 3dMD sequences of high-quality motion images of the full body, head, foot, and/or hand help promote and advance the creation of new wearable technologies that precisely adapt to a person's shape and enhance performance.

TECHNICAL SESSION 7: Medical Applications II

3D Morphometric Evaluation of Craniofacial Features in Adult Subjects with Marfan Syndrome #17

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Marfan syndrome (MFS) is a hereditable disorder of the connective tissue with an estimated worldwide prevalence of 1:5000, mainly caused by alterations of the extracellular matrix protein fibrillin-1. Cardiovascular manifestations of MFS, including aortic dilation with increased risk of dissection and rupture, are the leading cause of mortality. Therefore, an early and accurate diagnosis of MFS is crucial to prevent the development of complications, even if it may be difficult, due to the variable expression of the disease. It has been suggested that craniofacial abnormalities associated with MFS could predispose to obstructive sleep apnea, which in turn may promote aortic dilation. Since in a previous preliminary study on young subjects with MFS we pointed out some quantitative facial features never described before, we extended the study on adult patients, in order to better characterize the facial phenotype associated with MFS and verify the usefulness of a 3D not invasive quantitative approach for its early recognition. 3D facial images of 49 Italian subjects diagnosed with MFS without previous history of facial injuries or surgery, aged 18-60 years (18 males, mean ± SD age 37 ± 11 years; 31 females, mean ± SD age 40 ± 11 years), and divided in 5 non-overlapping age groups, were obtained by stereophotogrammetry. From the coordinates of 50 soft-tissue facial landmarks, linear distances and angles were measured; z score values were calculated comparing patients with healthy Italian reference subjects (332 males and 329 females), matched for gender and age group. Almost all subjects with MFS (96%) showed a shorter mandibular ramus than controls (mean z score = -1.8) and 100% of subjects showed a greater facial divergence (mean z score = +2.0), thus strengthening the findings of the previous study on young subjects with MFS. Furthermore, 98% of subjects showed a reduced ratio between posterior and anterior facial height (mean z score = -1.8) and 92% of subjects showed a reduced ratio between facial width and facial height (mean z score = -1.5), being both ratios influenced by an expected but overall mild increase of facial height. Remarkable gender differences or age-specific trends were not observed. Facial abnormalities pointed out in the current 3D morphometric study could represent traits of the phenotypic expression of MFS. Furthermore, since they are in accordance with the findings of our previous study on young patients, their detection could facilitate the early diagnosis of the disease, when the phenotype of MFS is not clearly evident or has not yet been clearly expressed. Further studies on more patients are needed to confirm the promising findings.

The Application of 3D Image Acquisition Systems to Palatal Rugae:
A Technical Improvement for Personal Identification? #19

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The modern 3D image acquisition systems have acquired in the last decades a growing importance in clinical anatomy and in different fields of application of physical anthropology, including also forensic issues. An example can be found in the development of novel procedures concerning the comparison of palatal anatomical structures, such as palatal rugae.

This study aims at exposing possible protocols of superimposition for the comparison of palatal rugae, useful for clinical and forensic purposes: the palate is acquired by a laser scanner (Dental Wing©). Superimposition is then performed according to the surface of the three main palatal rugae through VAM© software which is able to give back an estimation of RMS (root mean square) point-to-point distance between the two models. Models can be also assessed separating the right and the left side in order to test possible modifications of palatal structures in cases of maxillary expansion.

The 3D superimposition provides a chromatic visualization of corresponding areas (areas with full superimposition are represented in green, whereas possible discordances are in blue or red) that offer a visual depiction of the quantified differences, useful in clinical contexts.

The proposed protocol may therefore provide a relevant help in the assessment of palatal modifications in clinical anatomy and forensic anthropology.

Practical Advice: Navigating the Landscape for Using 3D Body Scanners in a Medical Environment. Do's, Don'ts and "Maybes." #23

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Background: The medical branch of sciences can be a close-knit, difficult fraternity to enter. This in part is due to sensitivities about historical incidents that border on what would colloquially be called "quackery," or "charlatanism." In the name of both protecting the profession as well as the patient, the equivalent of trade associations were created. These associations established standards for the medical profession. Later, governmental organizations developed as regulatory authorities. The private associations and public government agencies combine in such a way as to as to form what some have called an insular community. This "establishment" is a double-edged sword. On one hand, it has served its purpose by elevating the bar for quality of practitioners and consistency of care. On the other hand, the myriad of rules and regulations make it difficult for new ideas and new applications to enter from the outside. Worse, these rules have a tendency to change and can be subject to different interpretations. This paper gives a primer, based on practical experience on how to field a 3D scanner system into a medical facility, both for commercial services and also for research purposes.

Methods: There have been many opinions as to what constitutes a medical device. "Treat, Diagnose or Cure," is a general rule of thumb. If a device directly claims to do any of these, it probably falls under a "medical device" label and must be approved by the appropriate authorities for use on human subjects. Measurement and Photography are different in the sense that one can certainly bring a smart phone with a camera or a tape measure from a hardware store into a medical environment and use their respective functions. A 3D body scanner used in the clothing industry combines both photography and measurement capabilities, and herein lies the gray area between commercial functionality and possible research. The 3D scanner is capability of multidimensional measurements that reveal new insights into the shape of the subject in the scanner. These measurements were previously unavailable. By combining these newly available measurements and forming new ratios and an evaluation scale it is possible to quantify certain physical conditions, such as obesity. In a sense, a 3D body scanner can then fall into the "Diagnose" category.

Discussion: Placing a 3D body scanner in a medical surrounding without awareness of the regulatory environment is not a good plan. Because this is a gray area, certain approvals and procedures are recommended. The most straightforward path is to have a qualified sponsor within the medical community, preferably an actual M.D. perform the role of the Principal Investigator (PI). The PI generates a research construct, including the desired end goal. This construct contains the framework of how the data is to be collected, handled. analyzed and eventually presented. This forms the part of proposal to be presented to an Independent Review Board (IRB). The IRB is an unbiased committee of medical professionals, generally sponsored by a university that conducts medical research. Their role is to ensure integrity of the research, security of the data, evaluate the risks to human subjects and that the researchers are qualified and certified to perform the research tasks. An extremely important part of the IRB submission is the consent form that the human subjects must sign. Without such consent, certain data on the subject might not be able to be used and could be discarded.

Conclusion: This paper outlines the procedures for the IRB protocol process, perhaps the most expedient way to get a 3D scanner fielded for use within a medical environment. It can be a lengthy approval process and the submission can also be quite detailed, particularly for the Human Subjects section. However, once the IRB is approved and the protocol followed, the anthropometric measurements provided by the 3D body scanner can be utilized to their full extent and, more importantly, can also be combined with the subject's other medical information, such as blood work or prescription medicine. The paper also explores two other alternatives. One alternative is to submit a 3D body scanner to receive unconditional medical device approval. This has many drawbacks, chief of which is that existing scanning technology quickly becomes obsolete. Less expensive and perhaps more accurate and portable 3D scanners are rapidly appearing. Certification of one type of scanning technology could be an expensive mistake. Yet another alternative is to petition the authorities for a "Non-Invasive Device Exemption." This approach generally requires legal counsel and associated expenses. Pros and Cons of the various approaches will be examined.

Using Mobile 3D Scanning Systems for Objective Evaluation of Form, Volume, and Symmetry in Plastic Surgery: Intraoperative Scanning and Lymphedema Assessment #39

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Background: There has been ongoing development in the field of three-dimensional (3-D) Surface Imaging such as laser scanner and digital photogrammetry in recent years. Manufacturers tend to make new 3-D cameras compact, light-weighted, mobile, and user-friendly, similar to the development on the smartphone market. Although 3-D scans have been used for patient consultations and digital documentation in Plastic Surgery since the 1980ties, there has been no significant development lately regarding its use for objective assistance during surgery.

Patients, Material and Methods: Our research team presents the use of different mobile scanning systems (Sense, iSense, Artec Eva, and Thor) as a new intraoperative 3-D scanning method for plastic-surgical procedures. We present several cases of aesthetic breast shaping and breast reconstructions with implants and free tissue transfer, such as lipofilling and complete reconstructions with microsurgical free flaps. In the future, these might assist surgeons with the pre-, post-, and intraoperative 3-D analysis, choice of therapy, consultation, and documentation. Furthermore, we want to present the same scanners for the accurate assessment of arm and leg lymphedema patients. The diagnosis of lymphedema in patients and especially the outcome after treatment has been described with various methods so far. But in terms of clinical practicability physicians still rely on classical tape measurement. We compare volume estimation between the results of our 3D scanners against tape measurement and water-displacement.

Results: The 3-D scanners were successfully validated for their intraoperative application to several patients. An intraoperative, objective measurement of volume to evaluate form and symmetry was possible for aesthetic procedures, such as breast augmentation and reduction, as well as for breast reconstruction with lipofilling and free tissue transfer. 3D scanning was used for key steps in all these procedures with minimum delay of the procedures and instant feedback for the surgeons. There was nonetheless significant difference between the used 3-D scanners in terms of mesh quality and textures. We could also validate all mobile scanners as objective tools to capture lymphedema in patients for documentation before and after treatment. The biggest difference was shown against tape measurement, which is highly dependent on correct placement and the different estimation methods.

Conclusion: In this work, we share our first experience with the intraoperative use of new mobile 3-D camera systems, discuss pros and cons, and show selected patient examples. The newest mobile scanning systems showed highly accurate 3-D scans during surgery regarding the actual form, shape, volume shifts and differences. Furthermore, mobile 3-D camera systems were able to accurately assess lymphedema especially for the leg and may become the future chosen method to evaluate different treatments of lymphedema. Although the development of 3-D scanning devices rapidly increased, we still lack appropriate software development for medical usage. Newer software has to become more practicable, user-friendly, and especially versatile for different plastic surgical procedures.

TECHNICAL SESSION 8: Body Scanning for Apparel II

Virtual Design of System "Body-Dress" Improving with Scanning Technologies #41

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This exploration is aimed to improve the database used 3D CAD design to get more realistic virtual systems by means of 3D body scanning technologies. In reality, systems "body - clothes" have changed much when the pattern blocks modified under influence of different fabrics and clothes construction, while the virtual systems showed diverse results. In our research, to improve the process of virtual simulation and predict its results, the materials' mechanical properties were measured and air volume located between the body and clothes and other essential parameters of scanned dresses were calculated. To design more realistic virtual systems “female body-dress”, the database were especially promoted in accordance with demands of fit and balance influencing by the dress styles and textile materials. New database will allow to do more realistic simulation based on the synergy effect of significant factors combination including textile materials properties, fit indexes, and dress shapes.

Kidsize: Always Get the Right Size! #34

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This paper describes the two innovations underpinning Kidsize concept and presents the results of their validation. The first one is a mobile phone app to measure a child in 3D by taking two pictures. This new method is more accurate and consistent than an untrained person using a measuring tape at home or in the shop. The second one is an expert system that recommends the size that best fits the child and assesses the fit of the garment at different body areas. Project results show that it can provide nearly 90% right size recommendations, thus outperforming existing methods like age- or height-based size guides, which achieve 40 and 60% right recommendations respectively.

Automatic Morphological Classification with Case-Based Reasoning #48

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It is still a challenge for the apparel industry to develop good fitting products and underlying sizing and grading systems. This is due to the diversity of human bodies having the same traditional size but different morphotypes. Additional reasons are differences between different countries and special target groups such as young people or old people.
The objective of the iMorph-approach is the morphological classification based on body scan data to be used for size system development and to provide better fitting clothes. Additional applications include recommendations systems in online business and curated shopping.
iMorph is a unique approach to estimate the morphological classification of individuals based on body scan data. First, a morphological classification scheme was developed. It comprises 10 features and according ordinal scales. The analysis of the available body scan data showed that it is merely impossible to derive rules for the automatic morphological classification. Therefore, human experts visually classified a number of selected scans (data sets) by looking at the scanatars. A simple web-based application allows remote classification for invited experts. The resulting case base of classified scans is the core of a Case-Based Reasoning (CBR) system. It is able to compare the data of a new, unclassified scan with the scans of the case base. The most similar scans are the used derive a good estimation for the classification of the new scan.
The crucial element of this iMorph approach is the applied similarity model. The functions are specific for each morphotype feature because not all measurements are relevant for all features. An example may illustrate this: for the classification of the shoulders of a new data set, only a number of scan data related to the shoulders is relevant, for example breast girth, distance shoulder to buttock. The classification is then derived from the morphological classification of these most similar “shoulder cases”.
The described approach has been proved to be valid and comprehensive. It is flexible and extendable because each classification feature has separate similarity and retrieval functions with vast expert knowledge embodied and can be linked to various case-bases. Time consuming individual morphotype classification can be replaced by CBR technology and supports fashion product development as well as size recommendation in online retail.

Rapid Body Scanning Technology for a Virtual
Mass Customization Process in Garment Industry #43

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Nowadays the product development process in apparel industry is mainly influenced by the customer-customizing products become more and more popular aiming not only to improve fit but also to individualize and satisfy customer needs. Numerous tools have been developed all facing the same problems: How to take body measurements, how to take the right measurements, how to transport individual posture information and how to implement these data correctly into a product pattern based on a predefined construction system. Therefore body measurements and posture information both have to be linked by transfer equations to finish/ready measurements positioned on defined locations of the construction and finally of the product.

Most of the companies offering mass customization to their clients are working without scanning technology and without a fitting session- checking fit and design only in a very last process step- if at all-usually when the product is already manufactured.
Virtual Product Development is a powerful tool- not only for merchandising and promotion but also for design development, fit check and technical product development, closing the gap between missing real products and missing imagination of customers.

Body Size Predictions Based on Features and Estimating 3D Morphotype Mannequin for Virtual Try-on #42

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The current dynamics of globalization trade such as mass customization, rapid change in fashion new technologies of communication, the morphological evolution of populations and the growth of Web-based environment sales, involve a revolution in traditional retail methods of apparel industry.
For fashion companies which want to gain competitiveness, they need to increase their level of service as well as consumer's satisfaction. One of the main difficulties standing in the way of garment retail is the lack of an efficient try-on process. In a remote environment, the body shape of an individual consumer couldn't be measured physically in order to be matched with a specific size of a garment and ensure the proper garment fit. For solving this problem, in this paper, a new and innovative non-contact method is proposed in order to estimate the individual consumer's body dimensions according to their height and weight.
Before defining consumer measurements, we need to define the morphotypes of a given 3D database of anthropometric measurements. To accomplish this, we used the method of human body morphology shape detection proposed by Hamad M. and al. 2014.
Based on this methodology, from the given database of 3D anthropometric measurements and 3D scans, we selected n clusters and n representative 3D morphotypes (centroids of morphological clusters). Then, we defined an intelligent system to estimate consumer measurement. To match morphological description consumer to 3D morphotype, we developed a method based on comparison between 2D images of the consumer with those projected from the 3D morphotypes.
Finally, a geometrical model associated with reverse engineering techniques has been used to generate the 3D virtual parametric mannequins from the 3D body scanned of the morphotypes. This 3D virtual parametric mannequins associated to customer measurement can be used as a 3D consumer avatar.
This concept is used for Web-based environment or in market and verifies its applicability and by applying it to an experimental use-case concerning size garments recommendation in a Web-based environment and it can be implemented in virtual fitting rooms.

TECHNICAL SESSION 9: Digital Anthropometry & Ergonomics

Digital Assessment of Anthropometric and Kinematic Parameters for the Individualization of Direct Human-Robot Collaborations #27

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For the human-centered design of ergonomic work systems, usually population based anthropometric percentile data tables, e.g. ISO 7250 are used. Due to the recent trend to complex individual and small-batch productions, there is an increasing product and process variability. Thus, the need of robots without separating devices that can work in direct interaction with humans increases (human-robot collaboration, HRC). This form of direct collaboration between humans and robots is a major challenge for a human-centered and safe workplace design. The development of sensor technology, data processing as well as the interconnectivity with collaborative robots generally enables a flexible adjustment of the robot's trajectory to the human prerequisites. Yet, to enhance the individualization of direct human-robot collaborations a more detailed knowledge of the anthropometric and kinematic profile of the employee would be beneficial. Manual anthropometric and kinematic measurements are time consuming and expensive and therefore not suitable as a standard process. To overcome this issue, the presented research project focusses on the optimization of this process by using markerless motion capturing. The processing and possible use of the captured data will be shown by the example of a use case, where the human parameters are used for a virtual simulation and optimization of a HRC-workplace. Afterwards, a self-written software tool for the Microsoft Kinect v2 sensor is presented for the digital assessment of anthropometric and kinematic human parameters. In the

actual case, the anthropometric parameters are captured from a static T-Pose. For the determination of the kinematic profile the employee successively performs pre-defined max range of motion movements for each joint and degree of freedom. The motions were designed in line with the neutral-zero method.The data is stored in a comma separated value file. For the use with other systems it is possible to export the values with calculated offsets to the standard T-Pose. Further, preliminary results of a validation study for the digital assessment of the anthropometric parameters will be presented. The main objective of the presented work with markerless motion capturing is to enhance the digital collection of individual anthropometric and kinematic data. In addition, the possibilities and constraints for the use of these digital assessed parameters for customizable HRC-workplace designs are observed.

Thickness of Compressed Hair Layer: A Pilot Study in a Manikin #44

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Recent advancements in 3D anthropometry enable to link a subject’s 1D measurements to its 3D shape to achieve better fit, functionality, comfort and/or safety. Statistical shape models of the human head retrieved from medical images (CT or MRI) allow for such parameterized models, with a recently proven accuracy of 1.6 mm with only four scalp parameters. This induces opportunities for better sizing systems and mass customization of head mounted products. Due to the nature of medical images, hair is never present in these models. Head shapes constructed from conventional optical 3D scans however do capture the presence of hair. In current optical 3D scans, subjects wear a swimming cap, hairnet or wig cap to flatten and compress the hair layer and prevent artifacts, interferences and misinterpretations during scanning due to the presence of hair. Thus models based on medical images provide parameterized scalp models with proven accuracy. This might be required for the design of certain head mounted wearables were sensors/actuators should make proper contact with the scalp through the hair. However, many other products to be designed for closely fitting the human head will rest on a (flattened) layer of hair. Thus in these situations it might be required to take account of the flattened and compressed hair layer in the design process. Up till now, knowledge of the compressed hair layer geometry is rarely needed in the field of industrial design with only anecdotic numbers available. The uprising of accurate parameter driven 3D models of the human head and entailed applications will induce the need for further accurate quantification thereof.
Firstly, we present two a method to assess the thickness of the flattened and compressed hair layer by capturing hair thickness at a given point with a linear dial gauge. Secondly, we present another method to quantify the hair layer from points measured on scalp and hair layer. From this geometric information one can also deduce whether and to what extend the parametric scalp model approximates the head model with hair layer with the same accuracy as it approximates the scalp.
Effect of hair thickness was evaluated by measuring a manikin with and without wigs and caps that flattened and compressed the wigs. All experiments were thus conducted in vitro, but both methods can be transferred without burdens to in vivo experiments.
A hair thickness between 1.3 ± 0.4 mm was observed with the first method and 1.5 ± 1.3 mm with the second method. A small number of measurements indicate that the head form with flattened and compressed hair is predicted by the parametric scalp model with the same accuracy as it predicts the scalp form.
These pilot results indicated that for the design of head mounted products that rest on the flattened hair layer, a margin of at least 1.5 mm should be taken into account for eventual variations in hair thickness. For the design of (personalized) head mounted products, already established parameterized scalp models can be used without loss of accuracy towards the presence of a flattened hair layer. Further large scale and in vivo studies are required to confirm and fine-tune these results.

Using 3D Scanning for Improved Helmet Design #12

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"One-size-fits-all’ is definitely not a good approach to helmet design, especially for situations with the significant risk of head injury such as sports and industrial workplaces. Function of helmets is only given with perfect fit. But the complex geometry of heads was insufficiently defined by traditional measurement which captures length, width and circumference only as numerical values. Therefore, no head shape information was available so far. In contrast, 3D scanning-technology provides an innovative approach for analyzing head measurements and shapes.
Scientific analyses show remarkable variations in head shapes of humans within the same head circumference. Despite the real need for head protection systems, no reliable anthropometric German head data of women, men and children was available so far. The results of the Hohenstein R&D project „Textile-

based head protection systems"(IGF 16976 N) close this information gap. To collect exact three dimensional head data a specific scanning process was installed, heads of men, women and children were scanned and a database of 3D scan head data was created. Statistic evaluations as well as 3D shape analysis were conducted. Market share tables and virtual 3D shape models representing realistic head shapes of German population were generated and new innovative virtual 3D analysis methods for proving fit and ergonomic comfort were developed. 3D scanning-technology provides an innovative approach for the optimization of helmets in consideration of fit, functionality and design. In summary, the study results provide fundamental guidelines for helmet optimization in consideration of fit, functionality and design.

TECHNICAL SESSION 10: Body Modeling & Processing

A Parametric Model of Shoulder Articulation for Virtual Assessment of Space Suit Fit #38

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Suboptimal suit fit is a known risk factor for crewmember shoulder injury. Suit fit assessment is however prohibitively time consuming and cannot be generalized across wide variations of body shapes and poses. In this work, we have developed a new design tool based on the statistical analysis of body-shape scans. This tool is aimed at predicting the skin deformation and shape variations for any body size and shoulder pose for a target population. This new process, when incorporated with CAD software, will enable virtual suit fit assessments, predictively quantifying the contact volume, and clearance between the suit and body surface at reduced time and cost.

Development of a Finite Element Digital Human Hand Model #14

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The aim of this research was to develop an anatomically accurate and numerically feasible and stable finite element digital human hand model, which would allow accurate bio-mechanical behavior during movement and grasping. Therefore, correct anatomical geometry of the hand has been defined based on CT images, which has been then used for the definition of the finite element model. Using the finite element software, material properties and boundary conditions have been defined to obtain accurate movement of the bones and deformation of the skin. The result of the conducted research is a developed angle-driven finite element digital human hand model, which is numerically stable. Using the accurate geometry and correct definition of the material properties and boundary conditions, the finite element digital human hand model shows reasonable bio-mechanical behavior under movement.

Cloud-Based Communications for 3D Data

ShareMy3D, Oslo, Norway

ShareMy3D is a cloud-based solution for sharing 3D files of all sizes and formats. It has 2 main advantages: it can handle very large file sizes with its revolutionary compression algorithm and it does not require a plugin or program download, only an internet browser. This enables users to quickly and securely share their 3D models with anyone from anywhere.

IEEE Standards Association Initiative for Accelerating Immersive Shopping Experiences by Harnessing Cutting Edge Research & Innovation for 3D Body Processing Technologies

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The IEEE Standards Association Industry Connections program brings together focused interest groups to address standards related considerations in emerging technology areas. The Industry Connections 3D Body Processing group brings together an ecosystem of players to co-develop an assessment of standards needs and to propose new standard(s) around enabling 3D body processing which includes the capture, processing, storage, sharing and (augmented) representation for "Of-the-body" and "On-the-body" technologies. This exploration includes identification and classification of types and uses cases for 3D body processing; identification of gaps in existing nascent standards and recommended practices as 3D body processing spreads beyond first adopters; identifying needs and develop proposals for new standards and best practices for 3D body processing and adjacent technologies (like 2D augmented reality).

TECHNICAL SESSION 11: Scanning Methods & Technologies I

Body Part Modeling on the Phone #29

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In this work we propose a software pipeline which uses the inbuilt RGB camera of an off-theshelf smartphone, to create a 3D model from a set of ordered images. The motion of the camera is tracked visually and a subset of the images is processed to create depthmaps that are then fused into a single point cloud. Subsequently a textured mesh can be extracted. The software runs entirely on the phone in real-time, transforming the mobile platform into a portable handheld 3D scanner. The resulting 3D models are compared to 3D models created by a typical structured light sensor for mobile devices.

Photorealistic Texturing of Human Busts Reconstructions #13

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Recent developments in the RGBD sensors systems, lead to a new generation of sensors providing high quality color images along with moderate depth resolution images. Most state-of-the-art real-time reconstruction algorithms support colorized reconstruction by methods that rely on vertex colorization. However, the resolution of vertex colorization is directly linked to mesh resolution. High quality color images therefore require an enormous amount of vertices in order to capture image details. This leads to unattractive large model files, large memory consumption and long processing times. In this work we propose an automated pipeline that is able to texture low-resolution geometric meshes with high quality color images. Experiments evaluate the proposed method in challenging environments such as varying illumination and non-rigid reconstructions.

Accurate Irritation-Free 3D Scanning of Human Face and Body Sequences #15

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Two new 3D scanning setups for the fast acquisition of sequences of moving persons based on near-infrared structured light projection are introduced. Both systems consist of a pair of stereo cameras and a projection unit and are working in the near-infrared range (illumination wavelength is over 780 nm) which is absolutely irritation-free for the observed person. The first system is based on the so- called GOBO projector and the second system uses a multi-aperture-projection unit consisting of ten projecting components. Measurements of 3D sequences of moving persons and examples of changing facial expressions are given in order to show the power of the setups. The results obtained by the use of the different projection systems are compared concerning measurement accuracy and robustness.

INBODY: Instant Photogrammetric 3D Body Scanner #53

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The digital manufacturing processes initially developed in rapid prototyping centers are nowadays appearing not only in industry, but also in medicine. In particular, in orthopedics, the manufacturing of orthoses is following this trend. The digital manufacturing process of orthoses requires a scanning device for the three-dimensional (3D) digitization of the human body part whose deformity needs to be corrected. However, the slowness of acquisition phase of the recent body scanners may constitute a key issue of the overall process, especially for patients with mobility impairments.

This work aims at presenting INBODY, an instant photogrammetric 3D full body scanner. The motivation behind it is to speed up the acquisition phase of 3D human models, up to make it instantaneous. INBODY provides several features of interests in 3D body scanning technologies: *(i)* instant acquisition of the human body model; *(ii)* precision and accuracy of the resulting 3D model comparable with laser systems; *(iii)* affordable costs.

INBODY is built upon a modular and distributed architecture: in this paper we highlight its key concepts and illustrate its potential through a case study, the real time acquisition and the 3D reconstruction of a human full body and a human torso, used for the digital manufacturing process of orthoses.

Moreover, INBODY can be used also in other fields, whenever body measurements and 3D human models are needed (sport, medicine, fashion, …).

TECHNICAL SESSION 12: Anthropometric Studies & Surveys

The Cycle of the Shape Descriptor Suite: When do People Become Overweight? #24

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Background. An enormous amount of anthropometric data has been collected over the last decade from body scanning morbidly obese subjects prior to bariatric surgery. Even more anthropometric data has been collected by scanning these individuals post-operatively on a periodic basis. A set of shape descriptors and new adiposity indices were developed, previously described and presented. The shape descriptors mathematically classify the shape of the morbidly obese. The adiposity indicators use volume and surface units to define the degree of obesity by determining the “space” occupied versus traditional weight and height and are general in nature. When these formulas are combined and applied to scans covering individuals ranging from visually thin to somewhat obese, an interesting phenomenon occurs. Thin individuals, regardless of gender, have similar shape descriptor values. As these formulas are applied to scans of individuals who appear slightly overweight to noticeably overweight, the shape descriptors begin to mathematically differentiate physical shapes and the ratio of torso volume and torso surface area rapidly changes. The question investigated is whether the start of these changes mark the beginning of being overweight. If unchecked, it could then lead to the onset of the obese condition.
Methods. 3D body scans have been collected at a cosmetic surgery location in parallel with the collection of 3D body scans from various surgical weight loss clinics. In addition, a series of scans were also collected at a local fitness facility. Together, the aggregation of scans analyzed comprised a very good cross-section of body shapes and sizes. The shape descriptor suite and the adiposity indicators were applied to this wide range of body shapes. Height and weight were also tabulated. Successive 3D scans from extremely thin to morbidly obese provided a progressive simulation of healthy and unhealthy weight gain.
Results. The point, or rather points, where the shape descriptors begin to differentiate body shapes has a great deal to do with weight distribution. Proportionately thin females and males generally have a maximum torso circumference height near or at the hips measurement location. Thin individuals register high on the shape descriptor scale and have a greater preponderance of torso surface area vs. torso volume. As more girth is visually apparent, the maximum torso slice circumference begins to move upward, and the individual’s torso volume increases at a greater pace than their torso surface area. There appears to be boundary points where these shape formulas become valid. Individuals of both sexes who are extremely thin have similar mathematical shape values. These are the upper boundaries where the formulas do not apply.
Discussion. As weight gain becomes distributed on the body, females have a tendency to store fat around the hips, while males begin to exhibit weight gain in the abdominal area. There is a “normal” range for the healthy weight males and females as exhibited by their torso volume/torso surface area ratio. At a particular point outside this normal range, the rate of torso volume increases more than the rate of torso surface area. This raises the ratio and a shift in the maximum torso circumference height changes the shape descriptors. The combination of these detectable characteristics derived from 3D body scanning might be utilized to reveal insights into the onset of physical changes in the body. As such 3D body scanning could be a useful health and fitness “early warning” monitoring tool for the population at large.

XL Plus mMen - New Data on Garment Sizes #11

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As part of the R&D project "Plus sizes men" (IGF 17460 N) the special body shapes of men with body volumes and circumferences above standard garment sizes have been analyzed. New sizing charts for men with plus sizes have been generated, specific body shapes were identified and optimized basic patterns have been developed.
Lack of physical data for developing clothing in plus sizes: The demand from retailers for plus size fashion is continuously growing. The market share of large menswear on the market has increased significantly. Although there is a need for well-fitting plus size clothes, no reliable anthropometric data was available so far. For that reason, the "Plus sizes men" research project was initiated in order to develop reliable sizing charts for men XL plus. A sizing survey was carried out using 3D scanner technology. Within the project, 664 men with chest circumferences of 120 cm up to 175 cm were scanned.
New sizing chart for menswear, sizes 60 to 78: On basis of the survey results, new sizing charts for menswear were developed covering the German sizes 60 to 78 and describing five figure types as well as five body height types. The sizing chart "Plus sizes men" is linked to the SizeGERMANY sizing system, in order to achieve the widest possible acceptance on the market. Furthermore, time target group specific measurements have been measured and analyzed.

Definition of morphotypes: Body shape variety of big sizes is huge. Therefore, shape analyses were performed and morphotypes, e.g. specific abdominal forms of men, were defined.
3D body models as basis for fit mannequins, 3D pattern construction and simulation: On the basis of the new body measurements, virtual 3D body models were generated. These 3D models represent target group specific average body shapes, like the stomach shape, for individual sizes.
Optimized basic patterns based on 3D scan data: Optimized basic patterns for trousers and jackets were developed based on the 3D body models. These 3D models – available as polygon mesh – have to be converted into 3D NURBS planes to be flattened. After flattening, optimized pattern geometry can be reproduced. By translating 3D body geometric information into 2D pattern, the fit can be significantly improved.

Novel Anthropometry Based on 3D-Bodyscans Applied to a Large Population Based Cohort #56

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Three-dimensional (3D) whole body scanners are increasingly used as precise measuring tools for the rapid quantification of anthropometric measures in epidemiological studies. We analyzed 3D whole body scanning data of nearly 10,000 participants of a cohort collected from the adult population of Leipzig, one of the largest cities in Eastern Germany. We present a novel approach for the systematic analysis of this data which aims at identifying distinguishable clusters of body shapes called body types. In the first step, our method aggregates body measures provided by the scanner into meta-measures, each representing one relevant dimension of the body shape. In a next step, we stratified the cohort into body types and assessed their stability and dependence on the size of the underlying cohort. Using self-organizing maps (SOM) we identified thirteen robust meta-measures and fifteen body types comprising between 1 and 18 percent of the total cohort size. Thirteen of them are virtually gender specific (six for women and seven for men) and thus reflect most abundant body shapes of women and men. Two body types include both women and men, and describe androgynous body shapes that lack typical gender specific features. The body types disentangle a large variability of body shapes enabling distinctions which go beyond the traditional indices such as body mass index, the waistto-height ratio, the waist-to-hip ratio and the mortality-hazard ABSI-index. In a next step, we will link the identified body types with disease predispositions to study how size and shape of the human body impact health and disease.

The Development of a National Anthropometric Data Bank for Saudi Adults: The Initial Stage #55

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Although the Saudi Arabian apparel market is the largest in the Middle East, there is no data or current size standards to accurately define the anthropometric size and shape of Saudi population. In recent years there have been requests from some of potential investors in the apparel industry and consumers to provide relevant size reference material. There is an urgent need for such data bank especially with the country's newly announced 2030 Vision to diversify the economy by welcoming forgin investments and creating 35 industrial cities under the umbrella of Saudi Industrial Property Authority (MODON), where the localization of many industries including apparel is highly encouraged.
The main aim for SizeSaudi national survey is to develop a national anthropometric data bank for Saudi adults using 3D scan technology. A sizing system for both Saudi males and females will be developed as-well-as body shape analysis for the country's adult population. The project is fully funded by King Abdulaziz City for Science and Technology (KACST). This paper presents the summery of the planning phase of the project. Unlike similar national sizing surveys that have been conducted, SizeSaudi project may face different obstacles due to the conservative nature of the Saudi culture where privacy may be an issue especially in collecting 3D data for female participants. To solve this issue, we omitted the awareness campaigns and media advertisements that were initially proposed.
Five thousand Saudis adults aged 16 years or older will be scanned using three-dimensional body scanner. The scanner that will be employed by SizeSaudi is based on photogrammetry technique which works by projecting safe white light stripes on scanned subjects and capture the distortions of light stripes by cameras. The scanner has high resolution sensors with average point density of 25 points / cm^2, one second 3D scanning time, and five seconds calibration time. The automatic body measurement extraction is based on ISO-8559 standard. In addition to 140 3D body measurements that will be obtained from the scanner, manual anthropometric measurements and body composition analysis will be obtained.

A multistage data collection process will be employed. First, respondents will register and respond to questionnaire through the project website, followed by watching an introduction video about the project and the scanning process, signing the consent form, manual measurements and body composition analysis, and the last stage is 3D scanning. Questionnaire includes sociodemographic characteristics, body satisfaction health-related habits, and chronic diseases. After collecting data from participants, three different sets of questionnaires will be sent via email for participants who are willing to further participate in any of the sub studies including: marketing and purchase behavior, privacy, and dietary habits. Manual measurements that will be collected include stature, crotch height, crotch length, vertical trunk circumference, and armcye height as advised by the project expert advisor. Body Composition Analyzer will be used which provides weight and a complete body composition analysis for each participant in less than 30 seconds. Data include weight, body fat percentage, body fat mass, body mass index (BMI), fat free mass, estimated muscle mass, total body water and basal metabolic rate.
Data will be collected from five main regions in the country (Central, North, East, West, and South), where for female participants will be collected in 3D scanning centers inside female university campuses and for male participants in booths in main university lobbies as well as in shopping malls.
A one week training course by an expert from the 3D scanner manufacturing company for the research team on the 3D body scanner and related purchased software was conducted, while a second will take place next September. A series of experiments were conducted to test for synchronizing the three data sets; questionnaires, manual measurements and body composition analysis, and 3D scan data. Moreover, three samples of modest scan wear were tested to determine which scan wear will be used without jeopardizing the quality of the 3D scan data. After finishing the planning stage, a pilot study will take place in September 2016 with 40 participants, 20 females and 20 males before conducting the national survey.

An Attempt for Developing Albanian Anthropometric System within a Pilot Project #25

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Anthropometric studies are a useful and accurate method for product design. In the apparel industry, anthropometric data are an important component for producing high quality garments. Different countries update their sizing systems used for garment design. In Albania, there are more than 35 years that there have not been conducted any anthropometric study. During these years, there have been several studies but they have aimed for small target groups. Moving into the full cycle production has become a necessity for Albanian garment industry in the last years. There are few firms working with their own brand for the home market, but they use different garment sizing systems. Thus, it is essential for Albanian companies operating in garment and footwear industry to use an Albanian sizing system. Updating anthropometric data will help garment and footwear companies to ensure good quality for their products.
The scope of this work is to show a methodology for body digitalization and to extract anthropometric data by the implementation of 3D technology. This is the first and biggest attempt for undertaking anthropometric measurements by using 3D technology in Albania.
A target group of 115 students aged 18 – 25 years old were part of the study. All of them were female coming from different cities in Albania. Adapting of the scanning system Konica Minolta VIVID 910, for human body digitalization showed fast data captured and good quality of body digitalization. Advanced data manipulation and body dimensions extracting were done by using advanced software. This would open the way to a larger anthropometric study in the country.

TECHNICAL SESSION 13: Scanning Methods & Technologies II

Multisensor Optical-Electronic Device for Calculation of Surface Parameters of the 3D Curvelinear Object #10

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The research covers the operation principles and structure functional organization of specialized optical-electronic device for calculation of a volumetric object.
The purpose of the device is to build the 3D plane, which with the given degree of precision approximates the surface of the top and nape sections of a human head intended for implication in the production of customized head wear and elements of protective clothing or for other similar tasks related to the analysis of the 3D object shape.

The proposed device provides the ability to build the 3D model of an object under study by acquiring and analyzing the series of images of its surface continuously acquired from three or four optical-electronic sensors throughout the measurement process. The number of the optical-electronic sensors depends on the configuration of the optical-electronic device. Optical-electronic sensors organized in a given order relative to each other constitute a unified system, which in its turn is to be placed in the prescribed range of positions in relation to the head.

In order to simplify the procedure and enhance the accuracy of calculation of special coordinates for a set of points of the object surface and reduce the computational complexity of the developed algorithms we use the tight-fitting contact hat consisting of a set of special contrast markers., which is to be put on the head.

The following beneficial features of the proposed method and the optical-electronic device have the following beneficial features: (i) no strict requirements to interrelated positioning of the analyzed object and the system of the optical-electronic sensors; (ii) possibility to use commercially available web cameras as optical-electronic sensors; and (iii) no structurally complex and moving mechanical elements, which allow its mass use with no reduction in the accuracy of calculated point coordinates on the surface of an object required for practical tasks.

The experiments we conducted showed that depending on the interrelated position of the device and the analyzed object our optical-electronic device gives the calculation error of the 3D coordinates of about ±2 to ±7 mm, which is sufficient for practical tasks.

Software Synchronization of Projector and Camera for Structured Light 3D Body Scanning #16

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Current 3D body scanners based on structured light principle are expensive and somewhat bulky machines which limits their wider spread. One of the factors driving the scanner cost up is the requirement to synchronize projector and camera which requires either expensive system components or a costly customized hardware synchronization solution. We propose a software solution to the projector-camera synchronization problem which enables construction of low-cost 3D scanner using common commercial off-the-shelf components only: a projector, a camera, and a computer. We also propose a simple calibration procedure for precise measurement of delay time which is necessary to achieve proper synchronization. We have developed a prototype system for 3D human body scanning using the proposed approach which achieves projector-camera synchronization and enables data acquisition at 30 FPS.

4D|BODY – A System for Three-Dimensional Imaging of Surface of Human Body in Motion #50

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The article presents a system for 3D shape measurement of surface of human body in motion. The general system set-up is presented as well as measurement algorithms, measurement results and exemplary application of data acquired.

The measurement system consists of five directional measurement modules. Four of them are located in four corners of the measurement laboratory and a single one is located in the middle of the wall towards which the person being measured is facing.

The measurement modules utilize structured light projection (namely variation of Spatial Carrier Phase Shifting – SCPS method) where images of sinusoidal fringes are projected onto the person being measured and the analysis of raster deformation on object surface is used to calculate the shape of the object. The well-known problem of raster overlapping is solved by means of temporal (dedicated hardware) and spectral (optical filters) separation. A characteristic fringe introduced in each raster allows absolute phase calculation and transformation of all directional point clouds to a common coordinate system using local calibration of the directional modules and global calibration of the whole measurement system.

In every time-frame and for every directional module the raster phase value in each image pixel is calculated based on a single-frame seven-point method. In the first stage of image processing a binary mask of the measured object is created. Next, the characteristic fringe is found by means of one-dimensional Fourier transform. In the following step a phase map is created as well as a quality map (pixel quality depends on fringe contrast in its neighborhood). Based on these parameters' distribution a spanning tree method is used to create an unwrapped phase map. Finally, an absolute phase distribution in the image is calculated using the information about the characteristic fringe location.

System calibration includes: local calibration of each directional module (phase and geometry calibration using a calibration board with markers) and global calibration (registration) of all measurement modules

(based on measurement of a known object by all modules). Additionally, a dedicated gamma calibration for each projector-detector unit was introduced in order to decrease measurement systematic error caused by nonlinearities in intensity projection.
Current measurement specifications of the described system are: 60 Hz measurement frequency, 2 m x 2 m x 2 m measurement volume, 1 mm spatial resolution and 0.5 mm measurement accuracy.
Data acquired with use of the measurement system is planned to be used mainly for medical and entertainment fields. Measurement of full body surface allows taking measurements of lengths, volumes, circumferences during gait and other activities of daily living as well while performing other types of movements.

TECHNICAL SESSION 14: Body Scanning for Apparel III

From 3D Scan to Best Fit Products – A Cloud-Based Solution for Fashion and Workwear
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Finding the best fit size is one of the key success factors in fashion and workwear business. Real fittings are often not possible due to limited time, missing knowledge about the connections between the customer body and the size of a garment and the physical distance in the online distribution channel. The effects of these massive challenges are frustrated end customers, often paired with loss of sales for the retailer and an enormous cost increase in equipment projects in the workwear sector.
Human Solutions has developed a fitting solution that combines different key technologies to an integrated cloud-based solution:
1) A flexible infrastructure to generate customer-specific avatars, on the one hand, on base of statistical knowledge about the human body, its proportions, correlations, dimensions and shape, working independently from the degree of detail of the input information and, on the other hand, by using the 3D body scanner and creating individual avatars.
2) A standardized process and infrastructure for the integration of product-specific data into the sizing process, considering the individual fit characteristics of the product, which enables the fashion and workwear industry to design the base of the fitting process in an acceptable timeframe.
3) Access to a reliable and self-optimizing size recommendation approach, which is based on individual body measurements from the customer avatar. The focus is on product-specific size information and the relation between body measurements and garment measurements.
The fitting solution is integrated into an easy to access infrastructure of technologies, functions and applications via web services that allow companies to enter this innovative solution approach very quickly.
This integrated approach was validated in several evaluations in which the influences of our various key technologies and their specific realizations could be quantified and their individual effects on the fit result were proven. A variety of integration scenarios was developed.

Analysis of Tight Fit Clothing 3D Construction Based on Parametric and Scanned Body Models #49
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The contribution presents the study related to the use of parametric and 3D scanned computer body models for designing and constructing the skin-tight garments. A number of methods and systems have already been developed that allow an efficient 3D design of garment patterns in a virtual environment using the computer-based body models. Such systems usually offer solutions for creating the models of garments to be manufactured from elastic materials, which come close to the body. Here, the designer designs the garment and also constructs a 3D model of the garment on the surface of the virtual model of the body. After finishing the computer design of the surfaces that simulate 3D patterns, the transformation of three-dimensional to two-dimensional patterns is performed. As a prototype of the garment, on which the study was conducted, the model of a wet diving suit was chosen. Using the 3D simulation method on the parametric and scanned body model, we have analysed the fit of designed prototypes in static and dynamic body postures.

Study on the Basic Pattern of Man's Trousers in Southwest Area Based on 3D Scanning Data #20
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The research of clothing structure design is based on the structure of human body, which establishes closer links with the data relations. As the important part of bottoms, the trousers has changed with less area of styles, and its fit and beautiful appearance are particularly important. The aim of this research is to alter 3D

scanning data information, and transmit it into the way of 2D templates to research the trousers pattern. Through gathering the 3D human data about 500 young men whose age is 18-25 years in Southwest Area, the article extracted 31 key parts of the related data to be turned into 2D pattern, which aim is to reconstruct the basic pattern of male trousers. The first stage is using SPSS software to calculate and analyze the data, and establishing the database of young men lower body model. The second stage is fitting the ergonomics relationship between body shape and pants structure by extracting the point-cloud of key parts, such as crotch curve arc, the cross-section of waist, abdomen and hip, and ham root girth and so on, to reconstruct its model of shape relationship. The last stage is building the basic database of trousers in different regions, size and type, to satisfy the requirement of fit and comfortable with people in the future.

The Research on 3D Numerical Control Modeling Method of Lapel Collar #21

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Rolled collar is formed by the stand collar connected with top collar and the lapel, taking special attention to the folding ease on shoulder. Its overall appearance and clothing comfort play a vital role in clothes. Neck connects the head and the body.it is one of the body parts be covered by collar. In the basic female human body model, the key data is extracted to establish wire-frame model of rolled collar. The research uses model measurement function in the CLO Enterprise OnlineAuth software to set up the wire-frame model of lapel model. There are two aspects mainly in solving problem of digital control. The one is the structural changes caused by the neck key point changes in human body. The other is using the wire-frame model is to describe spatial geometrical shape and topological relationship of lapel collar. And to solve the digital simulation of lapel collar.

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