Book of Abstracts

3DBODY.TECH 2018

9th International Conference and Exhibition on

3D Body Scanning and Processing Technologies

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Editor and Organizer

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INTRODUCTION

Introduction

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3DBODY.TECH 2018 - The 9th International Conference and Exhibition on 3D Body Scanning and Processing Technologies was held on October 16th to 17th 2018, in Lugano, Switzerland. This event was organized by Hometrica Consulting - Dr. Nicola D'Apuzzo, Switzerland. This conference and its parallel exhibition aim to fulfill the demand for an international and multidisciplinary event focused on 3D human body scanning, measurement and processing technologies, methods and applications. This event is the world leading technical platform dedicated to these specific fields.
In the last two decades, 3D scanning and processing technologies developed in other industrial sectors were successfully applied to the measurement and scanning of the human body. Methods and techniques are continuously ameliorated, more efficient and performing scanning systems are produced every year and new software tools are developed unceasingly.
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.
Note: not all the presentations at the conference have a correspondent abstract and/or paper.

TECHNICAL SESSION 1: MEDICAL APPLICATIONS

Processing 3D Scans Using Statistical Shape Analysis and Automatic Pose Correction for Subsequent Orthosis Fitting

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In the medical field, 3D-technology enables the creation of individualized medical devices that are tailored to perfectly fit the patient's anatomy. After the acquisition of the patient's 3D-scan, the data needs to be processed before it can be used to design medical devices. Two of the biggest challenges in processing the 3D-data are patient posture and scan quality, where surface information is distorted by noise or foreign bodies. Automatic patient posture correction can be done in numerous ways, but utilizing a generic template model has several advantages. First of all, the template posture can be set to a particular position by the user, reflecting the therapy administered beforehand. The patient scan will then simply match the posture of the model. Additionally, the position of anatomical features of the patient scan can easily be identified with the help of the template model. Another issue needed to overcome is alternating scan quality, which can dramatically decrease the ability to closely fit an orthopedic aid to the patient scan. With the help of machine learning via statistical shape models (SSM), an algorithm can be trained from a dataset of 3D-scans to reconstruct the mesh without affecting the geometrical features of the patient. Afterwards, the repaired and corrected scan can be used to design and print a custom-made orthopedic aid such as an ankle-foot orthosis (AFO).

A New Method for Finding the Shoulder Complex Rotation Centre Using 3D Body Scanning

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To avoid radiation exposure to the body, the rotation centre of the shoulder complex is often assessed using the Optotrak motion capture system instead of X-ray imaging. Recently, 3D body scanning techniques evolved from static to temporal scanning. This study investigated if a time series of 3D body scans may be an alternative for motion capture systems focussing on the shoulder complex rotation centre which is relevant for exoskeleton alignment to the user's body. 13 Male participants participated in this study (age 24.8±2.4 years, stature 182.2±5.5 cm, body mass 80.7±7.3 kg). Motion capture data (Optotrak) and 3D body scans (3dMD) were collected while the participant performed predefined movements (abduction, anteflexion and a combination of the two). The helical axes method was used to calculate the rotation centre from motion capture data as reference. The 3D scans were processed modelling the upper arm as a cylinder or as a set of perpendicular slices to the centroid axis. Also, a point 30 millimetres below the acromioclavicular joint, assessed from the 3D scan, was defined

as the conventional method. The mean distance from the rotation centre of each individual to the mean rotation centre of the cylinder (19 mm), centroid (18 mm), conventional (16 mm) and helical axis method (21 mm) were much smaller than the distances between the 3D scan derived methods and the helical axes method (43-49 mm). The shoulder complex rotation centre location differed considerably between the four methods. Therefore, X-rays of the shoulder are necessary as a golden standard to indicate which method is closest to the real rotation centre and to determine the correction factor for each method that removes the systematic error. 3D body scans contain valuable anthropometric information and have the potential for biomechanical modelling since the random error does not exceed the error of the Optotrak motion capture system.

3D Profilomer Combined with Hyperspectral Camera for Simplified Rheumatoid Arthritis Diagnostics

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Rheumatoid arthritis is a disease, which significantly impairs patient's quality of life and ability to work. It has been proven that early diagnosis is of paramount importance, since early treatment has a higher likelihood for improving the course of the disease. Thus, the onset of the disease should be detected as early as possible. Changes in tissue oxygenation, blood concentration, light scattering and joint shape indicate joint inflammation, which could be detected and quantified using optical techniques. That is why a proposed system combines the hyperspectral imaging system and 3D profilometer. It enables measuring a spectrum of the reflected light from small joints with about 1 nm resolution, and a shape of the surface with a precision of about 0.02 mm × 0.13 mm × 0.02 mm. In this study a RA diagnostics prototype comprising of a hyperspectral imaging system and a 3D scanning system is used to aid the rheumatoid arthritis diagnostics.

Non-Contact Capturing of Burn Victims for Individual Combustion Supply

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For the treatment of combustion sore the patient receives compression therapy on the reconstructed skin to reduce the intensity of scars. In the public funded BMBF-research project "Smart Scar Care", the project consortium targets industrial pro-duced burn garments regarding fitting, compression, pore structure, and micro air-conditioning, while keeping the individuality of the treatment. The required make-to-order process consists of several sub processes: (1) Capturing individual body measurements with 3D-scanning technologies, (2) Product configuration, (3) Trans-fer of product data, (4) Interpreting geometry and configuration to calculate 3D-flat knitting model, (5) 3D-simulation to review compression results and product quality, and (6) fully automated production of individual burn garment. The talk under con-sideration will cover the first two aspects of this workflow.
For clinical environments, especially within emergency room situations, a stationary full-body scanner is not feasible. On the other hand, using a mobile, handheld scan-ning device brings its own challenges. We will address the feasibility of such a sys-tem in the targeted environment and show example cases. Especially for the body parts targeted in this project a motion-restricting pose is possible, both to reduce reproduction dispersal and keep a contact- and, therefore, painless relationship to the patient.
Afterwards, for configuring the individual burn garment the scanning results are used additionally. This implies a second layer of individualization, adding individual con-figuration to individual body shape. We will investigate the necessary set of interac-tion tools and illustrate their use. The resulting product configuration is then embed-ded into the previously mentioned make-to-order process, which will be briefly ad-dressed, here..

New Virtual Tool for Accurate Evaluation of Facial Volume

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Objective: The aim of this study is to develop a protocol to accurately measure facial volume through three-dimensional (3D) technology and virtual tools using free software.
Methods: Eighteen cadaveric hemifaces were evaluated. A tissue expander was inserted in the anterior maxilla region and 3D digital meshes of a face side were captured by a scanner at 4 stages of

controlled injection of saline solution into the expander (0, 3, 6, and 10 mL). Four virtual models of every face side were aligned in relation to the reference model (0 mL). A virtual cube (343 cm3) was added to the scene overlapping the aligned meshes. Volume difference from the virtual cube external section related to the mesh surface was calculated.
Results: Strong correlation between measured virtual volume and real expanded volume was observed (r, 0.997-0.999; P <0.001). Significance difference of virtually measured expanded hemifacial volume with and without expander was verified (P <0.001).
Conclusions: Protocol using 3D technology and virtual tools with Blender free software enabled precise calculation of volumetric facial variation in cadavers.
Keywords: three-dimensional image; face; plastic surgery; computer-aided image processing; photogrammetry; software.

TECHNICAL SESSION 2: 3D BODY SCANNING SYSTEMS I

BodiData's Patented Kora Scanner and Software System

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In October of last year in Montreal, I introduced BodiData, Inc. and initial look at the development of our multi-sensors handheld scanner.
In the 3rd Quarter (August) of this year, our Kora Handheld Scanner will be generally available to the marketplace. The Korea Scanner removes the limitations of the current state of 3D body scanning technology: size, mobility and clothing constraint.
In Montreal, the focused of the session was on the hardware aspects of the Kora Scanner. Here I would like to present the entire Kora Scanning System: Hardware, Software and Big Anthropometrics Data Set. There have been multiple patents already granted on our technology – additionally in 2018 we have a new provisional patent filed: describing a software system and method for interactively capturing 3D data using a handheld device with multiple sensors and providing semantic labeling of regions and sub-objects. The model may then be used for deriving measurement, displaying functional aspects of the scanned object, and determining geometric fit to other objects based on those aspects. I will be discussing our patented software process of:

- Scanning using the handheld device and stitching the 3D Optical point cloud of the subject together successfully regardless of the type or color of the clothing being worn.
- The 3D point cloud is further refined and annotated using depth data from a millimeter wave transceiver array. The constructed 3D point cloud may be call the “Subject Cloud”.
- Leveraging our anthropometrical large data set obtained from real world scans of 1M people, we generate a parametric 3D human models where the appearance, shape and size of models, its sub-objects or regions can be changed parametrically. The parametric 3d model is constructed so that each meaningful region of the model is labeled. The generated point cloud of 3D human models can be called the “Reference Cloud”.
- A best fit “Reference Cloud” is selected for the “Subject Cloud” and morphed into the “Subject Cloud”.
- The newly constructed “Reference Cloud” can be added to increase the data set further – enhancing the learning system.
- The full 3D surface model and region labelling can be pulled and measurements extracted.

We believe our innovative solution of a mobile 3D body scanner capable of scanning an individual while fully clothed and extracting his/her body measurement is worthy of discussion and sharing.

ScanLounge - High Volume Photogrammetry Scanning for Sizing and More

Alewijn MEDENDORP
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The ScanLounge is a mobile, full body, photogrammetry 3D scanning solution for high quality results.
In this presentation we will explain why we strongly believe that photogrammetry is the technique of choice. Actual case studies in different field will be explored, not just for sizing, but AR, medical, product visualization and memorabilia as well.
Scanologics initially started providing full service solutions for the 3D printed figurines and currently scans over 150.000 people per year. As participant in the RAAK fitting fashion consortium we have entered the field of sizing and have exciting new collaborations to share.

TECHNICAL SESSION 3: 3D FACE & BODY SCANNING IN MEDICINE

Novel 4D Whole Body Scanning Solution and its Medical Application

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One of the drawbacks of the traditional 3D whole body scanning is that it is capable of capturing only static models. In most of the cases it is impossible to properly analyze the way people move as they are not able to freeze their movement for a certain amount of time. In order to add a 4th dimension (time) to measurements, a system have to be built using stable ultra-fast 3D scanners. The presented solution meets industrial requirements for 4D measurements of dynamic objects. It is capable of acquiring up to 120 Hz sequences of high precision point clouds along with an information about its lightness and normal vectors. A spatial resolution of 1 mm is obtained with an inaccuracy below 0.5 mm. It was originally designed for a 4D human body shape measurement to support medical rehabilitation monitoring, however it is not restricted to this application. The system is composed of four directional measurement columns. Sufficient body surface coverage is possible thanks to an even distribution of modules, each consisting of 1 projector and 2 detectors – on the upper and lower part of the head. Their working principle is based on a structured light projection, specifically a single frame pattern approach which enabled achievement of the declared frequency. For this particular case a problem of synchronization (highly erroneous overlapping of the projected patterns) was solved. A sine modulated patterns are colored and distinguished using a spectral separation via color filters. Information about fringe numbers is encoded using an additional transverse modulation of the patterns. Retrieval of a single multidirectional output cloud is done using a set of dedicated algorithms, including phase unwrapping on a single image per detector, scaling into XYZ coordinates and common calibration. The high precision 4D data is very heavy. A raw 1 minute of 120 Hz scan requires around 360 GB of a disk space. In order to handle such data, the specialized software called FRAMES (Framework and Robust Algorithms for Models of Extreme Size) was developed. It has built-in 4D RAM (Random Access Memory) manager which enables efficient visualization, advanced multithread processing and analysis of such data. The presented 4D scanning solution was tested in a real-life environment. The possibility of performing 3D body scanning in time enabled the rehabilitation progress monitoring after leg amputation.

Potential of 3D Surface Imaging for Quantitative Analysis of Fat Grafting

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Autologous fat grafting is increasingly employed to address volume asymmetry and contour irregularity following breast reconstruction for breast cancer. However, there are no well-established objective tools to accurately measure change in graft volume and breast shape over time. Three-dimensional (3D) surface imaging allows for objective analysis of changes in breast shape and size, which clinicians and researchers can use to evaluate the effects of fat grafting. This study presents several measurements (Gaussian curvature, shape index, surface orientation, and volume) that can be extracted from 3D surface images of patients. These measurements are demonstrated on three patients (two patients after implant reconstruction and one after bilateral mastopexy) before and after fat grafting. The results of this study can help pave the way for clinicians and researchers to develop standardized metrics for objectively evaluating fat graft processing techniques. Using the proposed measurements, we were able to evaluate key shape and size differences in the 3D surface images before and after fat grafting.

Challenges with Life Surface Imaging

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Stereo photogrammetry has a clear role in clinical research, treatment planning and effectiveness assessment within the domain of medicine and dentistry. Recently more computational automatic 3D facial analysis methodology has emerged to increase the efficiency for data processing, this is

particularly beneficial for clinical trials as if often request large data size. The quality of automation is depend on two aspects, the algorithm/program need to be robust enough to cope the variance from the individuals and scenarios, and the raw data capturing need to be accurate. To the latter aspect, despite practical guide has published on top of the manufacturer suggestions, a detailed understanding of the error causation are requested, to eliminate further to the uncertainty from the process of facial surface capturing. This paper presents challenges of life surface capturing due to its dynamic nature and proposed a possible and practical solution.

RhinOnBlender

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Objective: The aim of this study is to develop an addon to Blender software, an accurate virtual planning protocol in rhinoplasty through three-dimensional (3D) technology and virtual tools using free software.
Methods: An addon to software Blender was developed with use a conventional photographic documentation to obtain a photogrammetry of patient. A virtual planning protocol was stablished to predict a rhinoplasty result, with the use measurements direct on the virtual mesh. After the process, a virtual guide was building with the possibilities to 3D printing to use in the surgery.
Results: Strong correlation between virtual planning with RhinOnBlender and the surgery results were observed. The 3D printing guide was usefull to orientate the surgeon during rhinoplasty surgery.
Conclusions: Protocol using 3D technology and virtual tools with an addon RhinOnBlender to a free software enabled precise planning to rhinoplasty surgery.

TECHNICAL SESSION 4: 3D BODY SCANNING SYSTEMS II

Digital Processing of 3D Full Body Scans for 3D Printing

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We present a cloud based solution for automated processing of 3D full body scans into 3D printable figurines. Digital representations of the outer surface of human beings have many different applications. One popular application is the physical production of 3D printed figurines. However, a raw 3D scan is not necessarily 3D printable, and if it is, it might be too fragile to be practically useful. Furthermore, straightforward printing of a scan on a state-of-the-art 3D color printer is not desirable due to the considerable color differences between the digital model and the physical reproduction. Therefore, pre-print processing is recommended. Manually performing these tasks requires specialized knowledge, software and a substantial amount of time. We automate these tasks and offer them as a cloud service in order to reduce processing time as well as financial costs.
In order to produce a decent 3D color print starting from a 3D scan, several types of processing are needed. We distinguish between (a) color corrections, (b) thickening thin components, (c) clutter and floor removal, (d) creating a watertight mesh, (e) adding a sufficiently stable baseplate, (f) rotate the scan so that the face looks into the right direction, (g) smoothing the full scan except for the face (h) optionally hollowing the scan and drilling escape holes and (i) some other trivial tasks such as scaling and rotating the scan. For each of the challenges mentioned, we present a fully automated solution to the problem.
Currently we cannot solve issues such as non-trivial missing parts in the scan and incorrect color reprojections in the texture. In the future we will investigate on how to solve some of the issues by taking a machine learning approach on a large database of manually corrected scans.

TECHNICAL SESSION 5: 3D BODY SCANNING & APPLICATIONS

Scanning Procedure of Female Torso Using Low-Cost Hand-Held Sense™ 3D Scanner

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3D scanning technology is widely used in medical and clothing applications as well as research projects. This paper presents our experiences with a low-cost hand-held 1st generation Sense™ 3D scanner (3D Systems Inc., Rock Hill, SC, USA) including free software Sense (V2.2). The shape of the female torso, including breast tissue volume, was determined using 3D surface scans. Female upper body area implies special requirements for positioning of participant and handling of scanner to gain good scan quality for reliable surface geometry. Lighting, settings and options, advantages and drawbacks of this scanner, including dimensional tolerance and repeatability measurements using mannequin and human body are addressed. Data processing and anonymization issues in the included free software are shown. Dimensional accuracy has to be proven first before using the Sense™ 3D scanner. For this purpose, a rigid plastic mannequin with markups, so-called fiducial points, was used. The distance from incisura jugularis to umbilicus height and nipple distance were measured using manual anthropometry compasses and virtual measurement from the 3D scan. The deviation was 0.1 % and -0.03 %, respectively. Repeatability of measurements was determined calculating average error parameter from 5 scans in standing and supine position (lying on the back) using the alignment procedure in MeshLab (v1.3.4BETA). Mean average error was 0.26 mm for both standing and supine position using either 4 or 19 pairs of points for alignment. Keeping in mind that the scanner is optimized for human skin and not for plastic surface, which sometimes causes reflections, this deviation can be judged very low. In addition, repeatability measurements were carried out on 3 pilot study participants. Mean average error for all participants and positions was 1.33 mm. Compared to the element size of maximum 3 mm this error is acceptable. Hence, the low-cost Sense™ scanner can be used in research projects dealing with human body geometric measurements.

ViALUX Sensor Design for High-Quality 3D Full Body Scanning

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3D full body scanners for the aquistion of high-quality data call for solutions tailored to the respective use case. The building blocks for both, hardware and software shall not only represent latest technology but need to be fused seamlessly in order to meet all requirements of advanced 3D body scanning. ViALUX scanners are based on such approach and are widely used in demanding applications for many years. The paper describes the successful integration of leading technology components yielding 3D scan units of outstanding performance.The key components and the parameters of the ViALUX scanner platform are explained and are illustrated by application examples.

TECHNICAL SESSION 6: 3D BODY SCANNING FOR APPAREL I

The Volumetric Analysis of the Human Body as Starting Point for Clothing Pattern Design

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The paper presents evaluation of the overall and microclimatic volume changes due to different upper limb positions simulating functional reaching movements for the aircrew personnel. The study was performed in order to evaluate the needed ease allowance added to chest and waist circumference for outerwear garments in order to fully achieve the wearing comfort. The accurate 3D body scanning was used and the impact of the upper limb position on microclimatic volume distribution was tested. The scanning data process was performed using a 3D laser scanner and a computer analysis. The raw scans were processed and reconstructed. After the scan reconstruction, the volume and the area were calculated.
The experimental study covered the objective measuring methods: the material testing, the 3D scanning, the scan reverse engineering modelling and the volume/area calculation. The volume calculations included both the overall volume calculation for the unclothed torso and for the torso dressed in the chosen outerwear jacket. It also included the volume calculation of an air layer formed between second and third - layered garments.
The clothing ensemble CE 0 is the control variable, the unclothed body. The CE 1 is the clothing ensemble combined from the underlying basic garments (undershirt, underpants, classical male

business shirt, and jeans) and combined with the bomber jacket. The three human subjects with the analogous body proportions (the height of 185 cm and chest girth of 100 cm) were scanned using the 3D laser body scanner Vitus Smart (Human Solutions GmbH) in an upright standing position according to ISO 20685:2010 changing only upper limb positions simulating functional reaching movements for the aircrew personnel.

Three-Dimensional Quantification of Foundation Garment's Shaping Effects

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Fashion garments sculpt the human body according to the up-to-date style. Foundation garments used to be out of whalebone and stiff materials. Nowadays thin and light shapewear aims to smooth obvious subcutaneous fat. Material, pattern, fit and formability of the body tissue influence the effect of shapewear. Thus, it is not known how much or even if shaping garments effect the body form. Moreover, there is a lack of standardized methods to analyze shaping effects of foundation garments. Up to now research focused two paths to analyze the functionality of shaping garment. First was to quantify the pressure applied, second was to measure the body changes achieved by the products. Governmental funded research project "Shaping Effects" aims to combine and pursue the research approaches. Project term is two years starting from April 2017. Therefore, most of the work is ongoing. The following presents preliminary results. 41 shapewear products were tested with HOSY apparatus to measure pressure gradient. PicoPress device was utilized to determine pressure between garment and manikin or human body respectively. 3D-analysis based on before and after scans was performed to measure changes in body geometry. Two test subjects tested shaping garments so far. Test methods were processed successfully. First results underlined the influence of material properties, body geometry and body tissue on shaping effects.

The Distribution of Air Gap Thickness and the Contact Area During Alpine Skiing

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The heat and mass transfer in the functional sport and protective garments is not only affected by the fabric properties but also by air gap distribution between the body and the garment and its change. Until now several studies have been conducted to analyse the impact of clothing fit, moisture content and body posture on the distribution of the air within garment. However, used methods are limited to only a stationary position of the manikin, whereas the air gap changes dynamically with body movement during sport activities due to bending joints. The present study addressed the quantitative and comprehensive evaluation of the 3D garment simulation tool and simulation of air gap distribution change during various activities.
In the first step the 3D garment simulation software was quantitatively validated by comparing these parameters obtained from this tool with the ones obtained from accurate 3D scanning method to assess its capability and accuracy. Next, for the first time, air gap distribution was calculated for garments on walking male avatar wearing t-shirt and sweatpants. The adapted post-processing method could discriminate the differences in the observed parameters over the body regions and among the phases of the movement. Finally, a male human body avatar wearing a coverall in tight and loose fits was simulated during alpine skiing and the developed processing methodology was applied to determine dynamic change of the air gap thickness due to this complex movement.
The presented study showed that the cyclic change of body movement was reflected in the change of the air gap thickness and contact area mainly in the concave body regions and was highly dependent on garment fit. The findings of this study can be used in theoretical models to understand how the body movement interacting with different garment fit can affect the heat and mass transfer process through the garment. Moreover, the outcome of this study could serve garment designers to improve the wearing comfort and protective performance of sport garments.

3D Digital Anthropometry in Case of Fit and Ergonomics of Army Uniform

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This paper focuses on analysis of human body measurements and movements – usage of laser scanning technologies for gaining measurements, movement amplitudes and biomechanical parameters in interaction within personal protective equipment (PPE). Analysis of the work postures and PPE were performed on 155 males who perform their duties in the Latvian National Armed Forces. In order to provide the comfort for individual wearers, it is essential to implement the body size correlations. The main premise is the availability of extensive and accurate information on the body measurements of certain populations or targets, as well as their distribution per body size groups or sizes. Acquisition of rapid and wide measurement data is now possible via the 3D scanning or contactless anthropometric data acquisition method. In addition to obtaining the measurements necessary for designing the clothes, the 3D technology also allows study different types of wearing habits, and the interactions between the human body and clothing layers, considering the body movement types and postures to be carried out during daily work processes, as well as the dynamics of these movements. The right clothing and equipment is of vital importance to the survival and effectiveness of military personnel. One of initial aspects is appearance and fit of uniforms and now the information necessary to ensure it can be obtained and processed using modern technologies: by non-contact anthropometric methods (3D anthropometrical scanner Vitus Smart XXL® is used in the study), data processing automation systems, pattern making CAD/CAM systems, etc.

Best Practice of Body scanning: Optimization of Clothing Processes in Companies and Institutions

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Issuing clothes to a large group of people is getting more and more important for companies and institutions. Today this usually happens by physical try-ons in several sizes. The use of body scanning saves time, reduces costs, and processes become more flexible and scalable.
Using the example of an European Army, it will be illustrated that issuing garments to groups of people with the support of 3D body scanning is more than just a recommendation of size with the highest possible fit rate. Fit philosophy as well as the direct connection to existing IT-infrastructures and supply chains plays an important role. With the separation of data acquisition and size recommendation, completely new process chains are possible for first issue, follow-up issue or special issues. Entering the digital world of body scanning with size recommendation brings new opportunities for inventory, procurement and supply management optimization as well as development and optimization of new garments.

Measurement Tables for Overweight and Obese Portuguese Children

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The main goal of this paper is to analyze the different children's measurements tables used by institutions of education, retail and apparel industry, aiming children's and youth in Portugal, comparing them with the body dimensions of Portuguese children with overweight and obesity, generated in a study using 3D body scanning technology - Kinect Body Imaging (KBI). This study is part of a PhD research project in the Department of Textile Engineering at University of Minho (Portugal), which has as general objective the development of a methodology of pattern design, using a reliable measurements table to supply the needs of this growing niche of the population. The period for data collection involved 6 months, starting in June 2016 and ending in November 2016 and was held in public and private schools of the first cycle of elementary education, located in the cities of Braga, Guimaraes and Vila Nova de Famalicao, in the north of Portugal. Throughout the research it was intended to analyze all the ages collected from 2-12 years, but it was verified that the images generated by KBI of children under 5 years were of poor quality due to the difficulty of keeping the children in a defined static position during acquisition.Thus, in order to avoid compromising the results, a cutoff point of the sample was performed, with the withdrawal of the children under 5 years old. From the sample of 816 children, 155 were excluded, remaining 661 for data analysis. From the weight and height collected, the percentile curve and the body mass index (BMI) of the 661 children was determined. The classification of nutritional status in: low weight, normal weight, overweight and

obesity, followed the criteria proposed by the World Health Organization (WHO) was also done for the sample. Data was statistically analyzed and the results are presented aiming the development of a children's measurements table of to be used by the industry for design of clothes according to the variations of age and proportion of the body of overweight and obese children, respecting their anthropometrics and ergonomic needs.

TECHNICAL SESSION 7: DIGITAL ANTHROPOMETRY & ERGONOMICS

Anthropometric Investigation of Head Measurements for Indian Adults

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One of the primary purpose of head related products is to protect the head. To perform their function well, these products need to be in close contact with the head, so in order to ensure a good fit, the designers need accurate anthropometric data. Till date only a few studies have been conducted on Indian adult population to acquire their head shape data and hence there is a need of conducting such studies so as to help in customizing products for Indian population. In this paper authors presents a preliminary investigation of four anthropometric parameters namely head length, width, circumference and anterior height. Thirty male and thirty female adults participated in the study, in which their anthropometric measurements were acquired from 3D head models developed from Computed Tomography (CT) image data. The acquired data was further statistically analyzed to create an understanding of the head shape of Indian adults. The mean values of the acquired data showed the difference in sizes of males and female heads. The analysis also showed a significant correlation between head length and circumference for both male and female participants.

Designing of Standard-Size Shapes of Heads for Selection from Customized and Mass-Produced Headwear

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The presented research introduces the method along with soft and hardware which allows to design gear and headwear and provides further easy selection of the necessary items among the standard mass produced goods which best match the individual requirements of a client.
The paper introduces the results of the research and the developed method along with the description of special soft and hardware which allows the fast and precise selection of an individual item of gear or headwear using the commonly available means.
The advantage of the presented method and the means is the combined use of information and data on available size ranges of headwear and protective sports headgear together with individual size and shape of a client's head, which guarantees reasonable price/quality ratio and allows a client to choose that precise item among the mass-produced goods which provides maximum comfort. Another distinctive feature of the presented approach is that it allows fast selection of the required item by means of creation and further use of the unique code index which defines the shape, size and other individual characteristics of a particular client.
To sum up, the devoted solutions which are introduced in this presentation combine the advantages of the customized approach and the selection from the mass-produced gear thus providing the fast and accurate way to choose a particular sports gear item or headwear that best matches the individual requirements of a client.

Process Considerations in 3D Hand Anthropometric Data Collection

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Landmark placement and methods, scanning tools, and hand position are several considerations scientists need to obtain reliable 3D hand data, especially for data collected for product design. The researchers of this paper are experts in product design and personal protective equipment. Specific anthropometric hand data important for glove design include finger lengths, crotch depths, palm and padding, back of hand, and wrist opening; these measurements can improve dexterity, gripping, hand entry, adduction, abduction, squeezing, etc. in the glove design. Traditional hand anthropometric studies are missing several key landmarks that are important to designing gloves. The researchers developed a new method, including crease lines as used by hand surgeons, to understand where

gloves need to flex, the fourteen joint locations of all five fingers, finger crotches, tips of fingers (especially when the subject has long fingernails), and wrist location. The researchers developed a protocol for landmarking that included notating the anterior and posterior sides of the hand, as they are different on each plane. Methods used to landmark hands is dependent upon the scanner used. Color scanners allow the use of felt tip, washable pens in color and stickers; whereas, non-color scanners require a bit more creativity, such as 3D shapes like pyramids so the scanner can see the shape. Heights of these 3D markers are also important, because if they are not tall enough the landmark will create an artifact on the hand.
There is also the need to consider how the hand is stabilized during scanning. For flatbed foot scanners, the process is simple, the subject places their hand on the bed and the scanning envelope captures the whole hand. With some portable technologies, the hand must be stabilized to limit sway due to the length of the scan. Different methods of stability frames were tested to enable reliable, smooth scans. In the past, only anatomical hand positions were measured for anthropometric data (not splayed or in ergonomic position). Several hands positions were tested, such as grasping positions and with fingers splayed, and measurements were compared across subjects to see how the dimensions of the hand changed depending on the position. Hand positions were also tested with and without gloves to test methods to visualize the glove to hand relationship and fit. The researchers developed methods to ensure repeatability and reliability of the data. Lastly, the subject needs to be considered. Because hands are so variable between subjects, several considerations are important, including: size of subject arm and hand, dominance, ethnicity (skin color), jewelry and nail length. All considerations for obtaining 3D hand scans are important to ensure accurate and useable data for product development and sizing.

RAMSIS Defense / Anthropometric Data for Ergonomic Applications - Benefits for Developing Defense Vehicles

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In the late 80's of the last century the German automotive industry initiated the project 3D Softdummy. The objective was a 3D anthropometrical correct digital human model for the ergonomic car design in the upcoming 3D CAD systems. Extensive measurements of the human body and behavior were taken at the Universities of Munich and Berlin and the final human model system was developed by Human Solutions. At the end the realistic 3D Digital Human Modeling (DHM) tool RAMSIS (Realistic Anthropometrical Mathematical System for Interior Simulation) was introduced at vehicle manufacturers and today has become the leading de-facto standard software for product ergonomics in vehicle interiors.
While at the beginning of the RAMSIS development the anthropometric measurements were taken manually, nowadays 3D body scanners have automated this process . Several surveys as SizeGermany, SizeItaly and actually SizeNorthAmerica were and are performed together with the automotive and fashion industry to acquire correct and up-to-date size information of the human body using 3D body scanner technology.
In addition to the automotive industry, manufacturers of trucks and commercial vehicles use RAMSIS to design the interior of vehicles and optimize the ergonomic product development, too. Moreover, the ingress and egress of vehicles is crucial for the ergonomic design of vehicles. Digital human modeling for the development of defense vehicles requires more than the representation of vehicle occupants, also the representation of body equipment and simulation of the impact of such equipment on the person is important.
In cooperation with the German Bundeswehr, Human Solutions has developed the module RAMSIS Defense. Soldiers were measured with and without body equipment / clothing in a 3D body scanner. From these data the relative location of equipment and cloth configurations on the body was derived. Finally, realistic 3D models of soldiers with body equipment and cloths were developed. To realistically simulate occupants in defense vehicles (land or air based), equipment must become an integral part of the extended human model. Simply attaching CAD-geometry to one manikin's element is not sufficient. Equipment size needs to be scalable with respect to anthropometry, impact on joint mobility needs to be considered with respect to material stiffness. Those aspects must be integrated in posture prediction algorithms to generate objective, reliable and reproducible results to help design engineers making better products that are safe, comfortable and appropriate for the occupants.
With the module RAMSIS Defense, engineers of vehicles for armies, police, fire brigades and even of motor bikes can carry out ergonomic examinations with and without equipment and check their effects on the product development.

TECHNICAL SESSION 8: FULL BODY SCANNING, MEASUREMENT & AI

Statistical Model for Human Measurements

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Recent interest in XR technologies and the corresponding applications (online sizing, virtual try-on) increase the demand for algorithms that allow to get precise information about the human body from digital data. While the data can be represented in quite different ways (3d body scan, multiview images, one image, body contour, etc.), we believe that a single image (under some reasonable constraints on human pose) may contain necessary amount of information to get precise tailoring measurements as well as a natural 3d model. Despite the fact that the reconstructed model looks similar to a person, it is not precise enough for taking human measurements. Therefore we primarily address the problem of estimating human measurements with a single image of a person wearing clothing.

We suppose that using visually realistic and detailed models in 3d is not necessary for solving the human measurements problem, so we propose our statistical model that is not based on a 3d mesh. We found that 2d slices (a spline-based closed curve) could be extremely helpful here. Therefore, our statistical model is represented by 2d slices that are located on areas that are expected to be measured. Here we should emphasize that statistical model is not based on 2d slices themselves, but on their parameters. In such way, we significantly simplify the model and reduce the dimensionality.

To get the measurements, we use PCA for regularization and make the initial guess. We found that the measurement error can be decreased by considering submodels that correspond to human features (arms, legs, etc.). Next, we compensate our changes in the submodels to get adequate human measurements in general.

Our second interest is to generate a 3d mesh from the measurements obtained. Here we use the idea close to the feature wireframe approach that was proposed recently. In fact, it compensates our human measurements one more time to get a more human-like 3d mesh.

Acquiring Accurate Body Measurements on a Smartphone from Supplied Colored Garments for Online Apparel Purchasing Platforms and E-Retailers

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Return rates for e-retail fashion companies are significantly higher than in-store sales. Twenty to fifty percent of online clothing sales are returned. Apparel retailers are haunted by returns based on sizing issues, with $62.4 billion in returns attributed to poor choices by the consumer in the USA. However, over the next ten years online sales are predicted to double, compounding the problem exponentially.

Garment sizing and knowing your correct size for a particular garment or brand while online shopping is part of the problem. It is the combinations of body measurements that determine sizing and sizing labels in clothing not usually one measurement. Most consumers don't know their body measurements when attempting to determine the size of a garment that they would like to purchase when shopping online and can have significant difficulty attempting to take their own measurements. This can lead to frustration and an incomplete sale or shopping cart abandonment. Many customers even resort buying a garment in two or more sizes and return the ones that do not fit, as they do not want to waste their time trying to determine which would be a perfect size. This adds to cost and waste affecting profitability. By the time these garments are returned to the vendor or manufacture they are out of season and usually not resalable at the original price because of the time lag and subsequent repackaging problems.

This research focuses on creating a fast-personal garment apparatus, system, and method for measuring body dimensions extracted from two-dimensional (2D) images captured by a consumer. Measurements of the individual are taken from captured pictures or photographs from their smart phones while wearing one or more coded dimensioning garments that have markings at specific locations that can be aligned with characteristic body features and key measurement areas. Computer vision is used to track these markings and extract key body dimensions. TensorFlow, a machine learning software application, is incorporated for object detection can be used to recognize colors and patterns on the garment allowing the garment to act as a measurement device for the body. The extracted dimensions could further used to predict additional body information such as; size growth and fit information, for example with fitness apps and workout appeal, or simply predicting children's wear and maternity wear needs as the body grows.

Applying Deep-Learning to Reconstruct Accurate 3D Body Maps Using Mobile Phones
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In this paper, we present the application of Generative Adversarial Network (GAN) deeplearning neural networks to build a 3D body-model using a very large – 100,000 body-scan – proprietary database. We learn the relationships between multi-viewpoints and the corresponding body-measurements and also use a hierarchical PCA in the semantic segmentation of body-information. We then use recent Augmented Reality functionality of mobile phones (ARkit on ios) to determine a Height reference for a person and then ask the person to rotate with their arms slightly apart. The video of this action, sampled at 25 framesper-second, provides a very large data set to fit our learnt body-models and derive measurements and body-shape information. The approach also takes into account differences in body-measurements due to breathing. The results of several female and male models bodyscanned using this method were compared with output from a TC2 KX16 body-scanner. The results were comparable, within 1 cm deviation on key measurements – bust/chest, waist and hips. We believe that this opens up the possibility of large scale adoption of 3D body-mapping for millions of consumers worldwide.

3D Human Models from 1D, 2D & 3D Inputs: Reliability and Compatibility of Body Measurements
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This paper presents partial results of a larger validation study of different Data-driven 3D Reconstruction (D3DR) technologies developed by IBV to create watertight 3D human models from measurements (1D3D), 2D images (2D3D) or raw scans (3D3D). This study quantifies the reliability (Standard Error of Measurement, SEM; Mean Absolute Deviation, MAD; Intra-class Correlation Coefficient, ICC; and Coefficient of Variation, CV) of body measurements taken on human subjects. Our results are also compared to similar studies found in literature assessing the reliability of digital and traditional anthropometry. Moreover, we assess the compatibility (bias and Mean Absolute Error, MAE) of measurements between D3DR technologies. The results show that 2D3D can provide visually accurate body shapes and, for the measurements assessed, 2D3D is as reliable as high resolution 3D scanners. It is also more accurate than manual measurements taken by untrained users. Due to accessibility, cost and portability (e.g. 2D3D built in a smartphone app) they could be more suitable than other methods at locations where body scanners are not available such as homes, medical or physical therapy offices, and small retail stores and gyms.

From Body Scans to Predicting Body Measurements
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Fit3D has developed the ability to predict body measurements using known inputs such as height, weight, age, and gender and then some simple subjective selections of human body segments. Fit3D is then using this information to help apparel brands take a body first approach to apparel design and omni-channel distribution with a goal to increase customer satisfaction, increase cart conversions, and reduce the overwhelming return rate.

TECHNICAL SESSION 9: 3D HANDS & FOOT SCANNING

Current Technology Landscape for Collecting Hand Anthropometric Data
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Historically, three methods have been used to collect hand anthropometric data. The oldest and most known method was developed in the late 1800's, where researchers used rulers, calipers and tape measures to manually collect data from a subject's landmarked hand, or from obvious parts of the limb that can be measured without landmarks (e.g., wrist circumference). The second method uses 2D imagery that is collected from the subject and then measured manually/digitally with rulers or calipers. A variety of devices can collect this type of imagery; including photo boxes, x-ray machines, flatbed scanners and photo copiers. These tools are convenient for collecting hand data, but can be limiting as they only collect one flat view of the hand, at one time. Over the last ten years, 3D scanning technology has been adopted for hand studies because of its' ability to collect data quickly, and with better

accuracy, as there are less steps and human error involved. 3D scanning allows researchers to collect data of an entire body part at one time, where it can be analyzed digitally beyond straight measures and circumferences. There are three types of scanners available in the market to collect hand anthropometric data, they include: 1) ones made specifically for hand scanning, 2) foot scanners and 3) hand held/mobile/tablet devices. But which 3D scanner should you select for your hand research? This can be an overwhelming decision, as there are so many options, and knowing what to look for can be confusing and quite difficult to find. Through experimentation with different equipment and hand studies, the researchers, developed a framework of key attributes that are important to selecting 3D scanners. They include: vendor/location, hand-held compatibility, scanner size, weight, envelope, supporting weight, price; along with scanner technology, timing, resolution, color capture, and file saving. Through this research, the authors desire to help others who want to purchase and conduct hand anthropometric research, to be more informed so can use their resources effectively and efficiently to have success with their work.

Grasping Hand Pose Estimation from RGB Images Using Digital Human Model by Convolutional Neural Network

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Recently, there has been an increase in research estimating hand poses using images. Due to the hand's high degree of freedom and self-occlusion, multi-view or depth images are often used. Our objective was to estimate hand poses specifically while grasping objects. When holding something, the hand moves in many directions. However, if the camera is too distant from the hand, it may move out of range. Widening the viewing angle, however, reduces the resolution beyond usable limits. One possible solution was developed by Kashiwagi - by setting the camera on an object, the hand's pose can be estimated regardless of its position. However, Kashiwagi's method cannot be used without estimating the fingertips' positions. Recently, another method using a convolutional neural network (CNN), useful for estimating complex poses, has been proposed. Unfortunately, it is difficult to collect the large number of images with ground truth needed for learning. In this research, we focused on creating a large dataset by generating hand pose images using a digital human model and motion-captured data using DhaibaWorks. We evaluated the model by calculating the distance of the estimated pose and ground truth of the test data, which was approximately 12.3 mm on average. In comparison, the average distance in related work was 18.5 mm. We also tested our method with ordinary camera images and confirmed that it can be used in the real world. Our method provides a new means of dataset generation: annotations are done automatically with motion capture technology, which reduces the time required. In future work, we will improve the architecture of the CNN and shorten the execution time for real-time processing.

A Simple 3D Scanning System of the Human Foot Using a Smartphone with a Depth Camera

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In recent years, online purchasing of clothes and shoes has become increasingly common. Although this is convenient, it can be difficult to choose the correct shoe size. While 3D foot scanners can accurately measure foot size and shape, this expensive and large scale equipment is not generally accessible for personal use, and there is a need for some simple and accurate means of measuring the foot in 3D. Recently developed smartphones with depth cameras enable easier measurement of 3D shapes, and this paper describes a method for measuring foot shape using a 3D point cloud captured from multiple directions by such a camera. As a 3D point cloud can potentially include noise or may omit occluded parts of the foot, we propose the use of a dataset of 3D foot shapes collected by a precise 3D shape scanner. We show how a deformable model can be generated by performing a principal component analysis on this dataset, minimizing error to recover a complete and high-accuracy 3D profile of the entire foot. We tested this method by comparing the 3D shape so produced to the 3D shape measured by the 3D scanner. The proposed method was found to scan foot shape with an error of about 1.13 mm. As demonstrated experimentally, the contribution of our work is in introducing the deformable model of 3D foot shapes based on principal component analysis, so that accurate shape models can be calculated from noisy and occluded 3D point clouds obtained via smartphone input.

Fast Foot Measurement System Based on 3D Measurement Network

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A multi-node 3D foot measurement network system is proposed based on digital speckle correlation method. For each node, two cameras build a binocular system, the corresponding points between the left and right cameras are established through the spatial correlation method. In order to improve the search speed of corresponding points, the epipolar and parallax constraints are adopted. The sub-pixel corresponding point location is achieved by Newton-Raphson iterative optimization method to improve the reconstruction accuracy, and the single-node depth data is finally reconstructed based on the stereo vision principle. Multi-view depth data is matched by means of the measurement network calibration technology. The whole foot data acquisition takes less than one second, which has a great commercial application prospect.

The Reliability of Using The Artec Eva Hand Held 3 Dimensional Scanner on Children's Feet

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The development of locomotor behaviour in infants and children is accompanied by the progressive development of foot shape and structure. Understanding this process requires 3-dimensional (3-D) scanning technology. Providing robust data on the development of the paediatric foot shape will help clinicians understand the typical trajectory of the foot and foot shape which could help inform understanding of how paediatric foot pathologies develop.
The collection of this data requires the development of a normative data set and will involve scanning a high number of feet, across a range of ages. Hand-held 3-D scanners provide the portability required to achieve this as they allow researchers to collect data in the children's natural environment. However, there are methodological challenges to consider (e.g. static weight bearing position).
To determine the reliability of our scanning method and analysis, 15 children were recruited, five from each age group (two, five and seven years old). Children stood in a comfortable bipedal stance, barefoot on a Perspex platform of 550mm height. Their feet were scanned three times, including the plantar surface through the platform.
To assess reliability using the intra-rater variability, the within subject standard deviation of the linear measurements and 3D coordinates of corresponding vertices, represented by the TEMs (Technical Error of Measurement) was calculated. The differences in linear measures and in 3-D foot shape between age groups was also quantified to assess if our method is sensitive enough to identify differences between age groups in this small sample.

TECHNICAL SESSION 10: FULL BODY SCANNING & PROCESSING

Working Group Progress for IEEE P3141 - Standard for 3D Body Processing, 2017-2018

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The 3D Body Processing (3DBP) Industry Connections Working Group, an adjunct group of IEEE P3141, Draft Standard for 3D Body Processing (3DBP), brings together diverse entities devoted to making recommendations for 3D body processing interoperability between creators and consumers of 3D body models. Members are mainly related to the apparel, footwear and accessories industry and include large retailers, scanner providers, data processors, hardware solutions providers, virtual fit providers, small start-ups and universities.
This paper summarizes the main activities conducted during the past year and provides an overview of the topics to be addressed in 2019. During 2018, among other activities, the working group published two white papers, determined industry needs with existing file formats, and planned a comparative study of full body using different anthropometric measuring methods, including traditional and digital.

Fitting Close-to-Body Garments with 3D Soft Body Avatars

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We describe the first end-to-end system, called VitalFit, for predicting the fit of close-to-body garments using soft body avatars. Soft body avatars may be constructed by registering our VitalBody template to existing rigid avatars, or directly to 3D body scans. The resulting soft avatar includes a tetrahedral mesh and soft tissue material properties that may be numerically simulated using the finite element method (FEM). Designers, fit specialists, and pattern engineers may create virtual garments and evaluate fit using VitalFit DX, a plugin for Adobe Illustrator®. Users can import existing patterns or create them anew, and modify the patterns using the familiar tools in Adobe Illustrator®. In VitalFit the garment and body are simulated together, with two-way coupling of forces and displacements. This allows us to predict how human soft tissues deform in contact with the garment. We can also predict stresses and strains in both garment and body. VitalFit can simulate the coupled dynamics of soft tissues and garment, during running and other activities of daily living. These new tools can be used to predict not only static fit, but also how a garment may function in real life.

Benchmarking a 3D Scanner: Understanding the Sources of Variance

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In order to successfully use a 3D body scanner, it is crucial to understand the quality of measurement reported by the scanner. Establishing measurement quality upon simple geometric shapes is a good first step, but understanding the complexities of measuring the human form is the needed benchmark, especially since the intended scan subject is a human who is breathing, moving, slouching, and changing in a variety of ways. In this presentation, I discuss an approach to benchmarking a 3D body scanner and explore strategies for disentangling the many sources of variation inherent in scanning humans. Our preliminary investigations reveal a few rather interesting results, including the importance of proper scan-wear and posture control.

TECHNICAL SESSION 11: 3D BODY SCANNING FOR HEALTH & SPORT

Breathing Cycle and Posture Affect Magnitude and Anatomic Measurement Site of Waist Girth in Healthy Adults: An Insight from 3D Scanning

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Waist girth is widely accepted as a simple anthropometric indicator of metabolic and cardiovascular disease risks. The aim of this research is to evaluate the impact of breathing cycle on the magnitude and anatomic measurement sites for waist girth using Hamamatsu 3D scanning. A sample of healthy adult volunteers (75 males and 36 females; age 27.8±7.5y and 23.6±4.2y respectively) participated in the study. Each wore form-fitting clothing (a swim cap, swimwear or lycra shorts and a sports top for women) which exposed the waist region. Each participant was scanned using a Hamamatsu BLS 9036 fixed scanner (Hamamatsu Photonics, UK) in three different phases of breathing cycle: end tidal (T), inspired (I) and expired (E); and in a scanner posture (SP) with arms and legs abducted. Acquired scans were analysed using the system's software (Body Line Manager Version 1.3). The effect of the breathing cycle on waist girth had the highest mean value at T (72.0 and 83.9 cm) in females and males, respectively and least mean value at E (70.9 for female and 81.9 cm for male). Adopting the scanner position resulted in a mean value of 70.5 cm and 82.9 cm for female and male respectively. At I, breathing cycle also altered waist girth significantly from the value obtained at end tidal ($P<0.05$) in females but yielded no difference in males ($P>0.05$). The anatomic measurement site for minimum waist girth had the highest vertical location at E (115.0 and 106.4 cm) for male and female respectively, the least at I (112.9 and 105.0 cm) for males and females respectively ($P<0.05$). In the scanner position end tidal the height level was at 114.7 cm and 105.1 cm for males and females, respectively. Breathing cycle and posture affect measurement value and anatomic measurement site of waist girth.

Prediction of Fat Mass and Validation Using 3D-Whole Body Scanner in Healthy Indian Males

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Background: BMI generally overestimates adiposity (i.e. body fat tissue) and underestimates excess body fat on those with less lean body mass.
Aim: We wanted to assess the hypothesis that Fat Mass (FM) measured by bio impedance analysis (BIA) is comparable to the predicted Body Fat Mass (BFM) using 3D scanned anthropometric dimensions.
Methods: The present paper investigates whether anthropometric measurements using 3D whole body scanner can provide clinically reliable prediction equation to assess adiposity. 3D whole body scanner provides a fast and precise alternative where the scanner gives upto 140 measurements within a few seconds. Intra-and inter-individual error margins in traditional anthropometric measurements frequently arises for large sample studies, besides, manually taking measurements are time-consuming and challenging to perform within acceptable limits. Six hundred and eight (608) healthy adults were scanned using a 3D whole body scanner and their body composition was measured using the Tanita Bipodal bioelectrical impedance analysis (BIA). 486 formed the development group (for the prediction equation) and 20% of the total (i.e. 122 formed the validation group) based on alphabetical order of participant's name. Linear regressions were performed to predict an equation wherein the body circumferential measurements like Waist Girth, Hip Girth and Chest Girth were predictors and Fat Mass was the dependent variable.
Results: Predictive body composition equation based on volumetric body circumference (girth) proposed for healthy Indian males is FM = 0.420 (Waist Girth) + 0.241 (Chest Girth) + 0.051 (Hip Girth) - 51.817. The predicted fat mass value was used for the validated population and we did not see much of a difference between the predicted and measured fat mass. The mean age among the 608 volunteers was 32.54 ± 6.3 years, weight was 71.26 kg ±7.8 kg and BMI was 24.1 ± 2.57 kg/mt2. Average difference between body fat measured by BIA - predicted body fat mass was 0.13 kg, median 0.50 kg, IQR: 0.80 to 0.20 kg, adjusted R2 0.74.
Conclusions: 3D whole body scanner technology offer defined and accurate automated anthropometric dimensions and measurements of body shape. Further studies are warranted to reveal important relationships between body shape, body composition and metabolic health across sex, age, BMI and ethnicity groups.

Estimating Body Fat from Depth Images:
Hand-Crafted Features vs Convolutional Neural Networks

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In this paper, we compare different approaches to estimate body fat percentages from simple depth images that can be captured by low-cost sensors. We implemented two frameworks, one based on hand-crafted features, using simple image processing methods to estimate directly from images a set of body measurements (e.g. areas, lengths girths), and one based on Convolutional Neural Networks, applying a direct regression from the grayscale maps representing the body depth, based on a pre-trained networks.
With these frameworks, we evaluated the fat percentage predictions obtained with the different methods on depth images of 350 subjects with known body composition estimated with a DXA scanner. Depth images were generated by extracting the z-buffer from the renderings of the 3D body scan models acquired on the group of subjects.
In our validation experiments, we evaluated the effect of different simulated acquisition setups, parameters settings, different image preprocessing and data-augmentation procedures and the addition of priors on height and weight on the prediction accuracy.
Furthermore, since the dataset used is composed of professional sportsmen and a control group, we evaluated also the ability of both frameworks of predicting the sport practiced by the subjects with a cross-validation experiment.
In specific, we propose a customized ResNet50 regressor to evaluate the whole body fat percentage of the subjects directly from the depth acquisitions. Using the same input data, we also set up a neural classifier to predict the sport category of the athlets.

Despite the limited numbers of subjects and the restricted variability of body types (all males, Caucasian, with a small number of obese), the results obtained are promising and can be considered a first step towards the development of quick and cheap body fat estimation tools that can be extremely useful for sport, health and fitness applications.

Breast Segmentation Procedure from Upper Body 3D Scans Using Open Source Software Blender

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The definition of 3D Finite Element (FE) volume models of female torso requires geometry information of naked surface and material properties of human tissues. Analog methods determining breast volume by water immersion of breast or plaster casts are still referred to as gold standard. However, the human body surface is nowadays digitized by 3D scanners, which have become handy and affordable in the last years. The term segmentation describes the strategy for separating breast tissue region from 3D surface scans of the female thorax. Different segmentation strategies are proposed in literature, either by outline definition or by creating a parametric surface (Coons patch) from boundary curves using fiducial points. The volume between breast base (artificial chest wall) and skin surface forms breast volume. In this study, 59 participants (19 to 67 years, bra size 75B to 95G) were scanned with a low-cost hand-held 1st generation Sense™ 3D scanner (3D Systems Inc., Rock Hill, SC, USA) in two different positions: standing upright on a turntable and lying on the back (supine), both with the palms of their hands resting on the anterior superior iliac spine. The supine position increases the visibility of the inframammary fold, a common problem especially in ptotic breasts. The breast outline was marked with skin marker. From the 3D scan data in *.ply file format containing geometric and color information, triangular elements representing breast tissue and other regions were selected in open source software Blender 2.79b. All selected regions were exported separately as *.stl files for further data processing in FE pre-processor Patran 2014.1 (MSC.Software Corporation, Santa Ana, CA, USA), where breast base was created and breast volume was calculated. Breast volume was compared to bra size and sister size groups, respectively, which usually shows relatively low accordance, indicating the importance of application and market specific determination of breast shape and volume.

Using the 3D Body Scanner in Elite Sports

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Using laser-based 3D body scanners in elite sports may offer a decisive advantage with respect to individual motion optimization and training. In the following, a brief overview of various applications of 3D body scanning in elite sports will be given as employed at the Institute for Applied Training Science. In many artistic sports, such as figure skating, gymnastics or diving, high rotation speeds for twists and somersaults are required for successful competition performance. To achieve those high angular velocities in air, athletes must adopt minimal moments of inertia (MOI) with respect to the rotational axis. 3D body scanners can easily be used to measure MOI and detect even small changes between different individual postures. Thus, optimal individual rotation positions for twists and somersaults can be determined. Five straight positions and four tucked positions were compared with respect to their MOI around the longitudinal and mediolateral axes, respectively. Compared to the standard up-right standing position, we were able to show that a straight position with forearms crossed in front of the chest yields a 12 % smaller MOI for the longitudinal axis. Regarding the mediolateral axis, a face-down tucked position generates an up to 30 % smaller MOI than a face-up tucked position. Moreover, for figure skating not only an optimal arm position but also closing the knees and twisting the shoulder and hip portions contribute to a significant decrease in MOI.
In ski jumping and snowboard cross, on the other hand, minimal aerial drag is a key performance factor. Employing 3D body scanner measurements there, aerodynamically unsuitable clothing can be identified. For ski jumping, 3D scans can also be used to reveal disadvantageous in-run postures, e.g. too big knee angles or aerodynamically suboptimal head, back or hand positions. Finally, anthropometric data of athletes as derived from body scanner measurements are also used for purposes of motion analysis and biomechanical simulations.

TECHNICAL SESSION 12: 3D BODY SCANNING FOR APPAREL II

Landmarking and Measuring for Critical Body Shape Analysis Targeting Garment Fit

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Industry 4.0 points to manufacturing that embraces both automation and customization yet apparel industries continue to be inhibited by the necessity for trial-and-error fittings to correct garment fit and while 3D technologies have gone far to automate fitting workflows, an inability to quantify body shape continues to plague automation integration. This paper explains why traditional methods of relating anthropometry to a 2D pattern are the root cause of poor garment fit and presents a solution for mathematically quantifying both body shape and garment fit. With an eye towards mass garment customization, and the theory that any pattern should be customizable for any human shape, theories on the relationship of 1D anthropometry and 2D block pattern were continuously re-trialed and honed over a thirty-year bespoke garment design/patter-making career. The methods presented were developed by combining common practices of triangulated pattern development with fabric draping and origami. A novel method of pattern block making was developed and found to be effective for accurate replication of body shape. Testing of the Clone Block™ proved successful for both men and women of a variety of sizes, making it gender neutral and well suited to automation. Landmarking and measuring requirements are mostly within the boundaries of ISO standards with a few novel requirements. While time intensive for hand measuring, the process is well suited for scanned measurement data and virtual environments. The Clone Block™ offers a critical assessment of body shape for automated garment fit, improved virtual size selection, more realistic virtual fittings, the optimizing of twin avatars to clones, and mass garment customization.

Scan to Pattern: How Body Scanning Can Help Transform Traditional Methods of Creating Pattern Blocks

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Body scanning provides one of the most efficient tools for recording information of the human body to support the development of body worn products. Traditionally the construction of garment patterns uses manual measurements and during the construction process applies some proportions, to create a pattern block. Traditional methods of drafting pattern blocks (slopers) apply very limited data from the body compared to the areas they cover and subsequently often require post drafting adjustments to achieve a suitable fit. Most pattern books have guidance on adjustments to blocks to accommodate figure variations. These methods of block construction are well established and understood and have been used to inspire new approaches and propose theories for pattern block development. With advances in body scanning it is now possible to generate more measurements allowing for the body to have greater context in the process of pattern construction. This research retains the established 2D drafting methods and looks to explore further measurements than those traditionally used to create pattern blocks, these resulting blocks could then better reflect the individual variations in potential wearer size, shape and proportion. As well as looking to determine suitable measurements from a Size Stream (SS14) body scanner to inform the development of pattern blocks, this research tests an established skirt draft using scan measurements, against a newly developed skirt drafting method which utilises the measurement capabilities of body scanning. The developed patterns are each tested on five dress forms. As well as assessing the resulting patterns, recommendations are made regarding how body scanning can be used to better inform pattern construction methods. This includes a contribution toward the theories of pattern construction, which will allow greater exploitation of body scanning technologies in developing better fitting and functioning garments. This research shows one means by which body scanning technologies can help to bridge the gap between traditional techniques of creating pattern blocks and the promising opportunities presented by body scanning technologies.

Efficient Virtual Garment Fit Evaluation Infrastructure based on Synthetic Avatar Target Customer Groups for MtM Application

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Customization becomes more and more popular and influences the product development process in apparel industry. In addition to individualize products, the fit of garments is very important for the customization.
Numerous tools are used to take the right measurements, to transport individual posture information and to implement these data correctly into a product pattern based on a predefined construction system.
In most cases the mass customization process takes place without a fitting session. Usually fit and design will be checked in a very last process step: When the product is already manufactured.
Garment simulation with human avatar-model integration have found its application fields in the fashion industry replacing real try-ons by virtual try-ons with respective savings potentials. Especially when systems become very complex, with high requirements of quality like in MtM scenarios, when there are dozens of technical parameters and decisions and rules defined that influence the pattern / fit of the clothing there is a high need to systematize the validation of the overall system.
Virtual product development is a powerful tool to change this process getting an early fit and design check. Putting together the knowledge of the 3D shape of the human body with the distribution of body-measurements, interdependencies and proportions and feeding this consequently into the process chain consisting of fit prediction / CAD with garment simulation is therefore the basic idea behind the system to be presented. By using an avatar test population representing the target group aimed for it is possible to check the sizing and to screen the fit of a product on individual bodies and postures in a quite short time to validate the MtM grading.
This paper presents a practical approach on the way to implement a virtual fitting session to a mass customization product development process chain.

Digitize Your CAD-Processes from the ECommerce Shop to the Marker for the Production

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At a time when the stationary trade is coming under more and more pressure, the online trade is booming and too much goods are available in the shops, manufacturers and suppliers are considering about new solutions and business models.
They are looking for strategies to merge online and offline, to speed up the processes, to verticalize the production to the end-consumers to offer more user experiences and customization to them and finally to initialize a sustainable production depending on fashion on demand.
In order to meet these requirements, the Gertsch Consulting & Mode Vision from Switzerland developed the platform “pod – Pattern on Demand®”, which offers to suppliers and manufactures of Made-to-Measure Fashion a consistent solution.
On one hand the platform offers a configurator, so the consumer is able to work as a codesigner and order the garment custom made – not only in design – but also on measurement.
At this point body-measurements from Scanners with different method (online/offline) are very helpful, to control and change the pattern to the right fitting size. In the past, Gertsch Consulting has already integrated different solutions – and is open to integrate upcoming new solutions and technologies.
At the other side the platform take care of all this e-commerce shop-orders and make fully automatically - with the CAD-Software GRAFIS® - the right markers for the production, including production orders to start immediately after receipt of an order with the production!
The advantages of such a platform are:
- Speed up the processes, by saving time and fabric;
- Fast and secure processing of individual made-to-measure orders;
- Reproducibility of orders;
- Easy to use, but with a great flexibility;
- Knowledge about pattern construction remember in the company;
- Ready to use.

From the point-of-view of Mr. Stefan Gertsch, the founder of Gertsch Consulting, is the Sustainability one of the most important and strongest challenges for the fashion industry of the future. In this respect, digitisation offers many possibilities of support.

TECHNICAL SESSION 13: 3D TECHNOLOGIES FOR APPAREL

Virtual Prototype of Clothing in Academic Environment

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Validation through prototypes is of fundamental importance in the new products development process. This procedure, common in industry, allows to speed processes, validating design, checking errors, identifying changes and observing new potential solutions. Also in academic environment, prototyping is used in activities related to the teaching of clothing pattern design. This procedure allows student to materialize ideas, providing tangible support for discussion, facilitating dialogue with teacher and visualizing the improvements throughout the process. The use of 3D CAD systems as prototyping tools is widely used in professional and academic environment. This promotes support for the development of engineering projects, namely mechanical engineering and in some segments in product design, such as furniture, electronics and others. The use of 3D CAD tools in apparel design has shown growth, but still resilient. Being the simulation of textile structures and virtual prototyping in 3D objects its main applications in this sector. However, 3D CAD systems present a high potential for the practice of design and fashion teaching. This paper documents the use of a virtual prototyping experience, in the development and evaluation, of the pattern design process of a functional garment, in an academic environment, referring the main benefits and disadvantages identified during the study, from the perspectives of student and teacher, relating them to the development and validation of traditional pattern-making methods.

The Design of Vocal Performance Dress Based on 3D Technology

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From the aspect of breathing movement, this paper takes the singer of the female singing as the object of the study, which is focus on the research of the body breath status of performers before and after wearing tunic dresses. Then analysis the relationship between performer's breathing movement and dress comfort. Base on this, the 3DCaMega human body scanning system is used to obtain the point cloud data of the performers in the same state to establish the virtual human body model and according to the model data and comfortable level. CLO3D is utilized to optimize the structure of tunic fitting. Finally, CLO3D is used to simulate the fitting and to prove the comfort of the tunic dress, Making sure performers can gain excellent artistic singing effects.

Study of Fashion Accessories Design Based on 3D Printing Technology

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The shape of clothing accessories includes internal styling and external styling. Through analyzing roles that 3D printing plays in spatial relations construction of garment accessories and in realizing these roles through utilizing internal processes and materials, 3D printing's functions in constructing the internal styling of garment accessories are highlighted; through analyzing its applications in functional additions and styling of garment accessories, 3D printing's applications in external styling of garment accessories are also reflected. Based on the manufacturing principle and material properties of 3D printing technology, this paper takes the castle backpack design as the experimental object, carries out experimental analysis and research. In the course of the experiment, 3D printing technology solved the difficulty of the castle modeling, the work is fine and the success rate is higher. The advantages of these experiments can be seen in every design and manufacture. The maturity of 3D printing technology makes the complex and changeable garment accessories design can be obtained by 3D printing technology. The success of the experiment provides a 3D printing technology information library for the design of clothing accessories.

TECHNICAL SESSION 14: ANTHROPOMETRIC SURVEYS & STUDIES

Foot Scanning in UK, USA and China

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Fit and comfort are almost synonymous in the footwear industry, with sales and brand reputation greatly affected by the fit offered by a product. Additionally, the end consumer is more aware than ever of the effect of poor fit on comfort and foot health.
While a degree of discomfort is occasionally accepted in some products, the majority of footwear will not sell if fit is incorrect. The growth of online sales is leading the industry to a greater transparency in fitting guidelines and size marking to reduce returns and secondary purchases intended to assess fit.
A large-scale study of several thousand pairs of feet utilizing 3D scanning technology has produced modern foot data which can lead to the optimisation of fit for a target audience. This can progress to improved population coverage of footwear, increased market potential and augmented comfort levels and general foot health.
Current foot dimension statistics and fitting guidelines are based on data collected a number of decades ago and evidence from this new survey demonstrates that foot shape and size have drifted noticeably over this period. This survey is providing the industry with the required data to evaluate and amend the understanding of foot shape and the dimensions necessary to improve fit.
The statistical evaluation of collected foot data will improve population coverage and enable more informed decisions to be made on fit and sizing to increase comfort and reduce returns.
The scope of this survey also includes the assessment of differences between the three demographics, UK, USA and China. Much of the footwear manufacturing industry has migrated to Asia from Europe and the US while the markets for this footwear remains to the west. This introduces new difficulties in fitting footwear that may have been modelled on Asian feet but intended for a western market.
Similarly, much of the tooling (lasts) used in footwear manufacture were designed in Europe and the US, yet there is an increasingly strong market for European goods in the immerging Eastern markets. Differences in foot shape may require new tooling for such a market.

Analysis of 1 Million 3D Foot Scans from North America, Europe, Asia and Australia

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The purpose of this study was to perform a preliminary analysis of 1 million 3D Foot scans. Data were collected with Volumental 3D foot scanners, located in footwear stores in North America, Europe, Asia and Australia. Foot length and foot width measurements were extracted from the 3D scans using an algorithmic method. Kernel density estimation was performed for each gender and region to compare the distributions of foot length and relative foot width across the studied regions. The results show that Asian customers have significantly shorter and relatively wider feet than customers in other regions.

3D Digital Anthropometric Study on Chinese Head and Face

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SizeChina-Hunan collects the latest data of Chinese head and face which will provide critical information for ergonomics. The accurate figure of the human head and face can provide vital advantages by designing wearable products, such as virtual reality (VR) and augmented reality (AR) headsets or safety glasses. However, the complex surface geometry of the human head and face presents a challenge for designers and engineers on account of the traditional ways of anthropometric surveys has numbers of limitations. The anthropometric survey of SizeChina-Hunan makes a combination of the traditional measurement way and high-resolution 3D scanning. The total number of subjects required at each site recruit 275 subjects with individuals ranging in age from 18 to 70 years and two sexes. Consequently, the goal was to recruit 2200 individuals totally ranging in 7 regional location respectively.

AVALYTICS PORTAL – A New Access Point for Anthropometric Data
Benefits for data owners and data analysts

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In the recent years more and more scan and measurement data became available due to new and cost efficient scanning technologies and the better acceptance of people to be scanned. A large number of scan data is acquired every day, in different formats and for different purposes.
At the same time there is a growing demand of the industry for anthropometric and demographic data. Manufacturer, brands, and designers have the desire to have best knowledge about their customers to provide them with the best fitting products.
The AVALYTICS combines benefits for both – the owner of collected scan data and the analyst that is searching for anthropometric data. AVALYTICS provides the opportunity for researchers and institutions that own scan and measurement data use the AVALYTICS infrastructure for easy and standardized access, or to share and commercialize the data with research community and the industry. For data analysts from industry and research AVALYTICS offers a unique access point to anthropometric data from different countries, projects, and studies. A variety of new filtering options and customizable population composition enables the user to analyze precisely the person group of interest.
Using examples of the ongoing Size NorthAmerica survey processes for data hosting, data import and analyses are demonstrated.

The Anthropometric Study of the Portuguese Population Using the 3D Body Scanning Technology - Its Contribution to the Improvement of Size Tables

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This paper presents the methodology used in the anthropometric survey of the Portuguese population. There is a lack of information in the construction of size tables and this could pose a big problem for brands mainly due to a significant increase in online shopping. Clothes should be comfortable and have a good fit. Size tables not adjustable to end users can represent a high return rate, making stock management very difficult. In Portugal there are some anthropometric studies conducted essentially by Universities and medical centres for civilian and military use. However these studies are made only for very restrictive groups of the population and do not provide the information that garment companies need to construct size tables. On the other hand, there is very few information at an European level.
There is an European standard, the EN13402, but when a garment company tries to use its information to build their size tables, they are faced with a lot of difficulties, mainly:

- The size tables used by industrial companies have more measurement points than the Standard;
- The EN13402-3 standard has some examples that are supposed to help companies in the construction of their size tables, however, the combinations of values are numerous, and if garment companies do not have any anthropometric data about their target population it is virtually impossible to construct an adequate size table relying only on the EN13402-3 Standard.

In order to help companies acquire the necessary information to construct their size tables, CITEVE and ATP did an anthropometric study on the Portuguese population, which was carried out on different parts of the country, with the inclusion of both men and women between the ages of 18 and 86 years old. The study was conducted using the TC2 body scanner, measuring 119 different points (waist, hip and bust girths as example).
The main results of the survey are:

- The basic statistics for the 119 measurement points (mean, standard deviation, …);
- The measurements identification of the “average Portuguese", male and female;
- The evolution of the measurement points (bust/chest, hip, waist), by age groups, which is important for the grading system;
- A tool to help companies to analyse if their size tables are adjusted to the Portuguese population and to better manage their stocks inside the shops.

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