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Book of Abstracts

3DBODY.TECH 2019

10th 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 2019 - The 10th International Conference and Exhibition on 3D Body Scanning and Processing Technologies was held on October 21st to 22nd 2019, in Lugano, Switzerland.
This event is organized by Hometrica Consulting - Dr. Nicola D'Apuzzo, Switzerland.
3DBODY.TECH Conference & Expo, the premier multidisciplinary international conference and exhibition on 3D human body scanning and processing technologies, provides a platform of eminent professionals, entrepreneurs, academicians and researchers across the globe to present, learn and discuss the latest in 3D body scanning and processing technologies.
The multidisciplinary character of 3DBODY.TECH makes it unique and not comparable to any other meeting related to 3D body technologies.
3DBODY.TECH Conference & Expo website 3dbody.tech give all information related to this event:
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: 3D BODY SCANNING IN MEDICINE I

Automatic Low-Cost Tool for Head 3D Modelling and Cranial Deformation Analysis in Infants

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Cranial deformation is a problem that affects an important number of infants. It requires different treatments, varying from repositioning techniques to surgery depending on the leading cause. The evaluation of the deformation is usually carried out using simple but low-accuracy methodologies such as visual assessment and clinical measurements. Accurate methodologies such as radiological tests and combinations of cameras and scanner are available but they are invasive and/or costly.
A patent-pending smartphone-based photogrammetric tool for the analysis of cranial deformation is presented. The methodology allows the generation of head three-dimensional (3D) models of infants automatically. It is non-invasive, low-cost and can be operated by users without any photogrammetric knowledge.
The presented tool consists of a smartphone app, a coded cap that is fitted to the head of the infant and processing software that yields the 3D models.
The data acquisition can be easily carried out during the routine clinical consultation. The patient is held by an adult while the application is used to obtain the data around the infant's head. The process is similar to a video recording, and the app guides the user during the process. The tool can tolerate the patient's movement so no immobilization or sedation is required. The whole data acquisition process can be completed in a couple of minutes. After the acquisition stage, the data is processed to obtain a 3D model of the patient's head.
The accuracy and repeatability of the process have been tested under ideal conditions. The obtained accuracy was found to be better than 1 mm. The methodology has also been tested in real conditions obtaining models useful for the evaluation of different types of cranial deformation.
The tool can be easily implemented in clinical routine. It requires minimum resources and provides a significant improvement of the techniques currently used for cranial deformation assessment.

Shapeshift 3D Repair ™ - A Fully Automated and Unsupervised Cloud API for the Reliable Reconstruction of Raw 3D Surface Scans Data

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This paper presents a study to quantify the reliability of the automatic reconstruction tool Shapeshift 3D Repair™ to create watertight, genus 0, precise and accurate 3D surface scan of the human body. Our methodology uses a precise baseline 3D scan acquired from a full body 3D scanner as an input of a scanning process simulator that emulates the properties of a common 3D scanner, the Structure™ by Occipital™, and behavior of a typical untrained handheld 3D scanner operator. The output of the

simulator is a raw scan (noisy and incomplete). Afterward, the raw scan is fed to Shapeshift 3D Repair™ which outputs a reconstructed scan. We express the reliability of the process in terms of Standard Error of Measurement (SEM). Using the girth difference between the baseline scan and the reconstructed scan, we express the compatibility in terms of Signed Mean Difference (Bias) and Mean Absolute Error (MAE). We compare our results with common reconstruction methods found in the literature and with other studies about the reliability of 3D Scanning, Plaster Casting and Traditional Anthropometry.

Context: To create custom medical devices and wearable, the patient's 3D geometry can be acquired using a 3D scanner. The raw 3D scans require post-processing as they are often noisy and incomplete. While organizations using 3D scanners put in place training programs, scans are often of poor quality. To this day, this issue is a hindrance to business models centered on 3D scanning such as the novel 3Dscan-to-3Dprint business model; inadequate scans must be manually corrected by the operators, which is a time-consuming offline process. The study is focused on the simulation of the scanning process and the scan reconstruction of the knee.

Results: A fully automated and unsupervised cloud processing services for the reconstruction of the knee has been implemented and is ready to be tested by user and vendors of 3D scanners. Reconstructed scans exhibit leg, knee and max thigh girth error under 0.1 cm, 0.3 and 0.4 cm respectively with 95% confidence level while producing properly defined surface that are manifold, genus 0, have good triangle aspect ratio, and have a single surface. With the recent boom of devices featuring an embedded 3D scanner, we believe that in given time, our technology can be accessible to millions of users without the needs of industry-specific hardware or skills.

Additive Manufacturing in Medical Applications needs Special Approaches - Practical Examples (in German)

Antonius KÖSTER
Antonius Köster GmbH & Co KG, Meschede, Germany

Die Möglichkeiten mit Additiver Fertigung patientenspezifische Versorgungen herzustellen sind vielversprechend.

In der CMF Chirurgie wird die Operation dreidimensional geplant und Modelle, Schablonen und Implantate additiv gefertigt und navigiert implantiert. Die Zahntechnik hat dank neuer Werkstoffe weitere Möglichkeiten der Fertigung von Zahnersatz und Kieferorthopädischen Hilfsmitteln erhalten. Inzwischen ist auch die Orthopädietechnik im Umbruch. Digitale Prozesse versprechen höhere Produktivität und Reproduzierbarkeit. Der Gipsraum gilt nicht als attraktivster Arbeitsplatz und steht doch für einen sehr wichtigen Bereich im Fertigungsprozess individueller Versorgungen. Können 3D-Scanner und Modelliersoftware ergänzt durch CNC-Fräsen und 3D-Drucker den Gipsraum ersetzen? Der Autor stellt zahlreiche Punkte dar, die bei der Planung und Einführung einer digitalen Prozesskette beachtet werden sollten. Kriterien bei der Auswahl der Scanner und die Unterstützung durch passende Vorrichtungen sind die Voraussetzung für die produktive digitale Modellierung. Sorgfalt während der Maßnahme zahlt sich durch fehlerfreie Umsetzung aus. Offene Schnittstellen sorgen für verlustfreien Informationsaustausch zwischen den Komponenten der digitalen Prozesskette. Die Konstruktionssoftware sollte den umfangreichen Modellieraufgaben gerecht werden und bei fortschreitendem Kenntnisstand Potential für die Zukunft bieten. Die Einführung digitaler Werkzeuge ist nicht mit einer zweitägigen Schulung abgeschlossen, es ist ein fortlaufender dynamischer Prozess, der entsprechende Priorität und Kapazitäten erfordert. Die Orthopädietechnik sollte Erfahrungen anderer Branchen – insbesondere aus den Gesundheitshandwerken – nutzen.

TECHNICAL SESSION 2: 3D & 4D BODY SCANNING

MOVE 4D: Accurate High-Speed 3D Body Models in Motion

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This paper describes the features and outcomes of a novel 3D/4D scanner developed by IBV. MOVE4D modules can be set up for different spatial, resolution and frequency requirements to cover a wide range of biomechanical applications in apparel, sports and health. MOVE 4D software automatically processes of the captured point clouds to provide dense watertight 3D meshes in motion, which vertices can be traced along the motion frames.

Man vs. Machine - Measuring People for the Apparel Industry
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Size Stream LLC, Cary, NC, USA
The Institute of Electrical and Electronics Engineers 3D Body Processing Industry Connections group is conducting a Comparative Analysis of Measurement Methods of 3D Body Scans (project details are given elsewhere). This article reports on the results of the first phase of the project. Over 60 subjects were scanned and manually measured at the Portland, OR site during November 2018. Here we report on the measurements acquired manually and those acquired by a Size Stream SS20 3D body scanner. The project goal in focus here is to understand the reliability and compatibility of measurements obtained through traditional 1D and advanced 3D methods. Scanner reliability was shown to have more than double the precision of manual measurements (via Coefficient of Variation analysis). Furthermore, we find that the variability of the two measuring techniques individually is greater than any bias between them (difference in the mean). After accounting for this bias, manual and scanner measurement techniques are compatible and can be used interchangeably.

TECHNICAL SESSION 3: 3D BODY SCANNING IN MEDICINE II

Interactive Visualization of Breast Shape for Breast Surgery
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While advancements in plastic surgery techniques and technology have facilitated improved aesthetic outcomes in both cosmetic and reconstructive breast surgery, communicating potential outcomes to the patient prior to the surgery, and understanding their aesthetic preferences for breast shape and size still remains a challenge. Unrealistic expectations related breast aesthetics can lead to patients' dissatisfaction with surgical outcomes. Currently, plastic surgeons rely on drawings or images of former patients to explain surgical procedures and their possible outcomes. The ability to visualize the expected post-surgery breast would, to a large extent, mitigate this challenge and aid both surgical planning, and inform decision making. In this work we propose a software tool that will enable visualization of three-dimensional (3D) images of patient's breasts and allow real time simulation of morphological changes on the breast.
3D surface images of the patients' torso were obtained using stereophotogrammetry during their clinical visits. The front torso area between the sternal notch and the umbilicus was captured. The breast region of interest was extracted semi-automatically from the 3D surface mesh of the torso and a computational model using Fourier based spherical harmonics (SPHARM) was created. SPHARM coefficients obtained from modeling were previously observed to have direct correlation with breast size and shape measurements, such as height, width, projection and ptosis. Simulation of breast shape changes was achieved by modifying these coefficients. We designed an application for visualization of the simulated breast on the 3D surface image of the torso with real time simulation of breast size changes by modifying the model parameters. The work in this study addresses design and development of the visualization software. Future work will focus on evaluating the visualization framework to assess surgeon and patient acceptance on usability, and feasibility for clinical translation.

ARSynth : Robust Real-Time Human Torso Tracking from Synthetically Trained Deep Neural Networks
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2 Arbrea Labs AG, Zurich, Switzerland
Robust real-time tracking of the human body is crucial to applications that benefit from live visualizations performed on the underlying body. Such applications could fall in the category of Augmented Reality for Human Bodies, finding great usage in the broader fields of Medicine and Apparel. Specifically, robust real time tracking of the female torso is a crucial component in the pre-visualization of cosmetic breast surgeries. In order to track a torso from monocular RGB input,

landmarks that describe the pose and shape of the torso have to be detected. Existing state of the art in algorithms for human pose estimation are dominated by deep neural networks and rely on the availability of large databases with high quality annotations. However, for the requirement of pre-visualizing cosmetic breast surgeries, existing databases fall short as they contain no or very few landmarks that can reliably help estimate the shape of the female torso. Therefore, by building on top of openly available databases of human character models, we create a pipeline for generating synthetic female torsos in both naked and clothed scenarios. We show that deep landmark detectors trained using such a synthetic dataset are capable of generalizing well to unconstrained real world images.

Progress in Human Breast Profiling using Shape-From-Shading

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Experiments have been undertaken in a continuation of a previously reported investigation into whether useful quantitative breast shape information may be deduced by numerical analysis of a single digital photograph of the breast. The work utilises the principle of extracting shape from image shading, known as shape-from-shading (SfS). The SfS method attempts to deduce surface gradients, and hence shape, across an object, by using the reflectance levels which are apparent in a monochrome digital image of an object. The method requires that the object has smooth physical texture and light even colouring. The significant feature of SfS is its simplicity, as it needs no special equipment, and involves the numerical analysis of a single digital photograph, which may be obtained with a mobile phone. The various features of SfS make it attractive for breast measurement. However, it is theoretically impossible to deduce two parameters of surface slope from one reflectance level, so the method faces difficulties which are prohibitive in many applications.
This major theoretical predicament may be overcome by using known surface shape information. The approach which has been investigated here involves obtaining profiles horizontally across the breast centre. This approach, which is feasible because of the regular geometry of the breast, has been proposed previously by the writer. The most recent tests of the technique, including both accuracy tests of the technique on objects of known shape and trials of breast profile measurement, are promising, and suggest that the concept is practicable. Sources of error are discussed. The impetus for further testing and development depends on the prospects of the use of breast information of this type, whether for medical or perhaps apparel purposes.

TECHNICAL SESSION 4: 3D BODY TECHNOLOGY FOR APPAREL I

That's the Way from 3D Body Scan to Individual Customized Clothing

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In order to successfully and sustainably produce individualized apparel in mass production, an integrated platform is required which can provide and connect various important and central modules. These modules have to meet different requirements depending on the viewpoint of customers, suppliers and producers.
Gertsch Consulting & Mode Vision developed with “pod- Pattern on Demand®” a platform that offers the possibility to connect these different modules in a common workflow, so that the processes can run fully automatically.
On the basis of his experience as a consultant and provider of a solution, Mr. Stefan Gertsch will present in his presentatioin the most important modules and explain the various requirements.

The Suitability of Body Scanning Measurement in Pattern Drafting Methods

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There has been much recognition that body scanning can provide more data on the human body than traditional measurements alone. Nevertheless, it is not always possible to extract the many measurements that are required by existing methods of pattern construction, due to the differences in the measurements captured between manual and body scanning methods. The conventional methods that are used for drafting pattern blocks do not incorporate data pertaining to body measurements to a large extent. This can be traced back to the fact that traditional pattern drafting approaches are from a time when obtaining some measurements were difficult and certain measurements were easier to

extract than others. To overcome the lack of data, post-drafting modifications are performed to accomplish an appropriate fit, and most pattern books are accompanied with detailed guidance as to how to adjust the blocks to take into consideration typical figure disparities. Body scanning technology makes it possible to acquire body configuration data that has been traditionally challenging to access. This type of technology can be employed to investigate body shapes and collate pertinent measurements. It can also be employed to delineate dimensions, something that was not previously possible. Moreover, appropriate scan data allows a challenge to existing drafting methods and the proposal of new ways of creating patterns that is based on actual measurements rather than proportional relationships. This study commences by analysing existing 2D pattern construction methods and the myriad outputs of body scanning technology to examine the extent to which body scanning can complement conventional pattern drafting approaches. Ten pattern-making techniques for bodices and trousers were assessed, and the measurements that were needed for these techniques were compared to the measurements that were generated by a body scanning system. The research established how well the measurements required for different drafting methods can be produced from 3D body scanning technology. The main contribution of this study is to highlight where measurements that are required for pattern construction be defined as outputs within body scanner systems. This would allow the body scanner to offer more suitable measurement support for pattern drafting methods.

Development of a Kinematic Human Model for Clothing and High Performance Garments

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In recent years, there have been significant efforts directed towards the 3D product development of clothing on virtual human models. However, developers legitimately criticize that static human models are not suitable for the construction of sports, medical, and protective clothing. A garment that fits a static shape may be very uncomfortable while performing daily tasks including walking, sitting, or reaching. Without a realistic body shape and natural human postures, it is difficult to create properly fitting apparel. To improve wearing comfort and shorten development times, clothing must be designed based on specific body postures. Moreover, innovative knowledge about the interaction between body and garment during movement must be considerate.

TECHNICAL SESSION 5: DIGITAL ANTHROPOMETRY & ERGONOMICS

Localizing Anthropometric Landmarks Using 3-D Surface Features

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Accurate localization of anthropometric landmarks is crucial for processing and analyzing 3-D anthropometric data. For example, landmarks are used to extract dimensional measurements from 3-D scans of human bodies. They can also be used to fit a template model to the scans such that a correspondence across the scans can be established. From this correspondence, we can perform statistical shape analysis to understand the variabilities of human shapes. In this paper, we propose a new method for localizing anthropometric landmarks using a combination of 3-D surface features and the latest deep learning techniques. The method makes use of geometric features represented as descriptor vectors. We first identify a set of locations that exhibit salient geometric features. Then we use pre-registered 3-D models to train a classifier for each geometric landmark. With the geometric landmarks, we fit a template to the data scan. The full set of anthropometric landmarks can be predicted from the template-fitted model. We validate our method using the 2012 Canadian Forces Anthropometric Survey (CFAS) dataset where 2,200 full-body scans were collected.

Selection of Protective Helmets Based on the Scanning System

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This publication presents the results of creating a service for individual on-line selection and customization of protective helmets for active sports and recreation. The service is based on the use of developed and patented hardware and software solutions that enable creation of three-dimensional shapes of the surface of a client’s head, the inner surface of a helmet and the subsequent virtual

combination of a client's head and helmet in order to calculate the vector of parameters of matching the anthropometric features of a client's head.
As a means of generating the primary data on the surface of a head, a mobile phone or a developed hardware scanner can be used. The service also provides an objective selection of the best fitting helmet with consideration of the individual subjective preferences of a client and analysis of a client's experience in using helmets. After selecting the best fitting commercially available helmet for a specific client, a helmet can be adapted using a specially designed inlay of a variable thickness in a helmet.
The adaption of a helmet ensures its maximum conformity to the shape of a head. Adaption is carried out on the basis of a special, inexpensive and easy-to-use helmet inlay. The thickness of the inlay is calculated automatically that ensures the best possible conformity with a customer, providing comfort and safety. The conducted experimental studies, as well as the reviews of customers who participated in testing the system, confirmed the desirability and accuracy of the selection of helmets based on the developed technology.

Designing Physical Human-Machine-Interfaces for Exoskeletons Using 3D-Shape Analysis

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Exoskeletons are a promising future technology to assist workers in high demanding workplaces (e.g., activities in or above head level or lifting heavy loads) and to reduce critically strained body parts (e.g., shoulder or back). Classical exoskeletons generally consist of a mechanical structure parallel to the body segments, actuators for force generation, a control unit (in case of active systems) and human-machine-interfaces (HMI). HMI either fix the exoskeleton to the body or transfer supporting forces from the exoskeleton to the human endoskeleton. At the same time, they need to satisfy safety and comfort requirements. Concerning force transfer too high pressure as well as play within the HMI must be avoided. Precise knowledge of the anthropometric changes in various body positions and muscle states is, therefore, the prerequisite for the design and dimensioning of HMI.
This article presents a procedure for designing individual HMI based on 3D shape analysis using the example of activities at head level or above. Based on the general approach the evaluation of the anthropometric changes of upper extremities due to different limb positions and muscle states (relaxed and tensed) is described. Furthermore, the process of data fitting for integrating the individual body parameters into the CAD-construction process is introduced.
Three human subjects were integrated into the experimental study, representing different figure types according to ISO 8559-2:2017. Body postures were scanned using the 3D laser body scanner VITUSbodyscan (Vitronic GmbH), characterizing daily postures of production activities in or above head level as an example for industrial work. In order to compare the scans in relaxed and tensed muscle states as well as in different limb positions with high precision, physical markers and handholds were used. Raw scans were processed and reconstructed with ArthroScan Software tools (Avalution GmbH), 3D shape analysis was calculated for anthropometric changes of the upper arm. In a first step, orthogonal planes to the upper arm were generated and multiplied using Geomagic Freeform to gain intersections with the arm. In the next step, the intersections were fitted into ellipses using Matlab. Finally, the ellipse data formed the basis for the automated CAD-process to create an individual HMI. The results of the study reveal a strong indication that individual human-machine-interfaces are needed to achieve satisfaction concerning fitting, force transfer and safety aspects.

TECHNICAL SESSION 6: 3D BODY SCANNING & MEASUREMENT

Smartphone-Based Precision 3D Body Scanning
Applications in Apparel and Footwear Markets

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We present an overview of current 3D scanning technology and how it could be of help to the apparel and footwear industry to reduce the return rate, increase conversion, and improve future product development. We further discuss the traits of smartphone-based 3D body scanning solutions.

Real Avatar Production - Raspberry Pi Zero W Based
Low-Cost Full Body 3D Scan System Kit for VRM Format

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EIDEN Inc., Tokyo, Japan

We would like to introduce Raspberry Pi Zero W based 360-degree full body shooting / 3D scanning system kit in order to create “Real Avatar”. “Real Avatar” is a word for photo-real 3D Humanoid Avatar. System configuration, flow, operation and resulting 3D scanned model are shown in this paper. In order to create mesh and texture, we use Photogrammetry software, RealityCapture, on Microsoft Azure virtual machine being configured with NVIDIA GPU. We also briefly introduce VRM format which is 3D Humanoid Avatar format that has the potential to be widely used for various VR/AR apps and platforms.

TECHNICAL SESSION 7: 3D HAND & FOOT SCANNING

Comparison of Glove Specifications, 3D Hand Scans,
and Sizing of Sports Gloves for Athletes

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Gloves are used in many sports as a form of protective gear and to enhance performance. Inadequately fit gloves can be detrimental to an athlete’s ability to perform. As the population of female athletes grows and diversifies, it is important to ensure glove fit and performance across the plethora of sports. Despite improvements in the availability of anthropometric data, measurements of the hand remain limited. In recent years, 3D scanning has improved to capture complexities of the hand. 3D scan data of the hand offers potential to improve the sizing, fit and design of gloves for sports.
There is a need to better understand anthropometric hand data in relation to female athletes and sports activities to improve future glove fit standards and performance. The purpose of this study was to collect, compare, and analyze 3D hand scans (30 subjects) versus actual glove specifications and sizing of commonly used sports gloves. A close fitting golf glove (FootJoy Women’s StaSof) was selected for comparison. Scans were taken of each subject’s dominant hand (landmarked in 30 locations for accuracy) with the Occiptial Structure Sensor and iPad, and measured with Anthroscan software. Detailed specifications of the gloves that related to measurements of the hand were recorded and compared to the population measurements to determine how well the selected glove model fit each subject. To better serve diverse users, results suggest that traditional glove sizing is inadequate and more anthropometric data of the hand are needed to inform better glove sizing and fit. Based upon the findings of this study, future studies will be conducted to evaluate various glove brands and activities.

Development of a 3D Grading Method for Shoe Lasts Based on Scanned 3D Foot Data

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In the shoe manufacturing sector, products are typically designed for a small number of sample sizes, whereas all other shoe sizes in the range (for example, 2 to 4 shoe sizes below and above) are scaled using grading methods. However, the grading process significantly affects the fit and thus consumer acceptance. In this context, the shoe last forms the basis for all additional components to be used, such as insoles, midsoles, outsoles and heels. The entire shaft construction is based on the last as well. It also determines the fit of shoes. However, a method once established in the 1930s and still used today for the grading of shoe lasts is limited to only two dimensions, i.e. last length and technical ball circumference. The entire last is enlarged or reduced on the basis of these dimensions. The 3D CAD systems available today still employ the principle of mechanical last copying based on machines from the 1930s. Thus, the technical potential of these CAD systems is far from exhausted.
An innovative grading process allows shoe companies to better utilize and significantly expand the performance potential and technical capabilities of their 3D CAD systems. As the required amount of manual work in preparation for grading and last generation is considerably decreased, development times are shortened.

"My Bauer" - Showcasing the Use of 3D Foot Scans in the Mass Manufacture of Custom Skates

Ales JURCA 1, Raymond BOISSONNEAULT 2
1 Volumental, Stockholm, Sweden; 2 Bauer Hockey, Blainville QC, Canada

Bauer is the largest producer of hockey skates in the world, already outfitting many professional players in their products. Before implementing 3D scanning technology, Bauer relied on foot casts to make custom skates for pro players - but capturing the geometry of players' feet using this method was complicated and time-consuming, and only highly trained specialists were able to execute it.
Today, after introducing scanning technology into their production process, Bauer has replaced manual foot casts with 3D models entirely. With foot scanners active in over 300 stores across North America, Europe, and Asia, they are able to offer "My Bauer" custom-made skates to the mass market.
To build their custom skates, customers simply scan their feet in one of these stores. They can customize each of the skate's main components (such as eyelets, liner, tongue, and blade) and add other personalized elements (such as player name and number). The skates are then manufactured directly based on the 3D foot scan, achieving an outstanding fit for every unique shape.
To our knowledge, this is one of the most significant instances of 3D foot scans being made available to a wide audience and used for the mass production of custom footwear.

TECHNICAL SESSION 8: 3D BODY TECHNOLOGY FOR APPAREL II

Development of a Jeans Sizing System for Young Black Pear-Shaped South African Women Using a 3D Body Scanner

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The South African pear-shaped Black women's jeans market has been confronted by fit dissatisfaction, although there is a growing demand for jeans. This study was approached from a viewpoint that jeans do not fit a large population of this consumer group and investigates the issues related to this problem. Local manufacturers and retailers currently use an adaptation of the British sizing system to suit their customer profile. Not much research however, has been carried out on developing a sizing system for the pear-shaped figure type, which makes up a sizeable portion of the population in the country. The intention of the study was to establish key variables for developing a jeans sizing system for Black South African pear-shaped indigenous women. A total of 60 Black women aged 18-35 years at the Cape Peninsula University of Technology were scanned for body measurements using a 3D body scanner. Body measurement differences were examined by using a quantitative research approach to establish the difference between waist and hip measurements. The findings revealed an average drop value of 39cm between waist and hip circumference for a Black pear-shaped figure, in comparison to a drop value of 24cm for a standardised sizing used by the clothing industry. It is recommended that the major stakeholders in South Africa conduct a national anthropometric study to update sizing systems, by using 3D body scanning technology, which provides accurate and consistent measurements of the human body.

CLO3D Fashion Design Software - A Perspective for Virtual Thermal Modelling of Garments

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Emerging 3D simulation tools for fashion design offer an opportunity to use their output for thermal simulation of clothing performance. The requirement posed to such software is accurate simulation of air gap thickness and contact area between garment and skin, since these parameters are mainly responsible for heat and mass transfer through the clothing. In this study, 3D garment simulation software - CLO3D - was systematically validated by comparing fabric draping on simple object (Cusick drape test) and complex geometry of anatomic human body (male and female standing avatars) obtained from CLO3D, with the ones obtained from laboratory tests of actual samples. The simulations of Cusick's draping test were compared based on top view photos of fabric, draped on the round table. For the full body and garment simulations, actual garments, identical to the simulated ones, were confectioned and 3D scanned on the stationary manikin; and finally compared for accuracy of the air gap thickness and contact area size. CLO3D showed an excellent simulation accuracy of these parameters, being within natural variability of draping of actual garments (Fig. 1).
CLO3D software opens new horizons for the thermal evaluation of clothing; through virtual simulation of draping clothing in different body postures, during movement and using this information as input to physical models of heat and mass transfer through air and fabric layers. Furthermore, such a series of

models can be coupled with a mathematical model of human thermal physiology and thermal sensation; to obtain virtual user feedback in different scenarios before even any prototype has been made.

Analysis of Thermal Comfort of Clothing with Different Textile Material through Thermal Simulation

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Thermophysiological comfort is one of the most important aspects of wear comfort. Currently, there are no software solutions available for the combined consideration of material characteristics, fit and thermophysiological behavior. Thus, a laborious empirical process is typically required to determine an appropriate design matching new textile materials for pattern cuts as well as changing climatic conditions. A detailed wear trial in a climatic chamber supports this process. The objective of this research is to analyze the thermal comfort of clothing with different thermal characteristics through the simulation of heat regulation in the human body, microclimate, clothing, and environment.

Evaluation of the Accuracy and Suitability of Low-Cost RGB-D Sensor for Automated Air Gap Measuring in the Apparel Industry

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RGB-Depth motion sensing devices are designed to capture the human body in full size including its motion, whereas gaming versions of these devices are available at acceptable prices for end users. ReconstructMe SDK was already reported as a powerful library which is capable to work with low-cost body scanning devices. Their combination allows the real-time 3D reconstruction of the body and the development of custom applications in C language. Hence, the objective of the current work introduced in this paper is to evaluate the RGB-D sensor of Asus Xtion PRO Live for application in the apparel industry in general and for automated body geometry detection and air gap evaluation in particular. Previous reports on low-cost sensors and systems have demonstrated that these devices already provide sufficient accuracy for certain measurements in the apparel industry. Due to their low price, they could be used in software applications designed for end users. For current evaluations, an upper torso was scanned both without clothing and with shirts of different sizes and colors. Measurement errors were evaluated and an algorithm for automatic gap evaluation based on generated meshes was developed.

TECHNICAL SESSION 9: 3D BODY SCANNING FOR SOCIAL SCIENCES

The Use of 3D Bodies in a Computerised and Immersive Virtual Reality Body Image Intervention

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Body image disturbances are associated with eating disorders such as Anorexia Nervosa and Bulimia Nervosa, supporting the importance of developing interventions that specifically target body image. Most interventions focus on targeting sociocultural aspects of body image as opposed to the perceptual component. Here a perceptual body image intervention was employed, based on categorical judgements of body size (‘thin’ or ‘fat’) following an existing cognitive bias modification technique. Previously, this intervention, has been piloted in 2D in females with heightened body concerns and Anorexia Nervosa. Findings suggest that by using inflationary feedback the program can modify categorical thin-fat body judgements, with improvements in psychological self-report measurements, and these changes were maintained at follow-up. The 3D bodies were computer-generated, calibrated based on body mass index, and presented in 2D in the computerised intervention. In the current work we present this intervention delivered in 2D and in 3D virtual reality (VR). Using VR allows for life-sized (scaled 1:1), volumetric presentations of 3D body stimuli in an immersive environment. While further research of this intervention technique is needed, preliminary findings suggest that it may be a beneficial addition to body image treatment.

The Development of a 3D Body Scan and Composition Database to Assess Body Size Perception in Psychological Research

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Recently, there has been a shift towards the use of 3D scanning technology in body size perception research. Based on limitations of previous methodologies there is a need to develop and validate female body stimuli that are high-resolution, photo-realistic and biometrically accurate, and modern technology makes this possible. The aim of this project is to generate a database of full-body stimuli using 3D scans of females, varying in both BMI and body composition. This data will be used to generate female body stimuli that can be used in future research to improve the methodological assessment of body image and body size perception in both clinical and non-clinical settings. 3D full-body scans were taken using a 3dMD scanner, body composition data measured using a Tanita bio-impedance scale and physical measurements (chest, waist, hip and arm circumference) taken using a tape measure. The combination of these technologies will enable the statistical mapping of human body shape and composition change and variation across a range of different heights, ages and BMIs. The analysis will initially focus on Caucasian females aged 18-45 years old. Data processing techniques and preliminary analysis will be presented and the implications in relation to future research will be discussed.

Real-time 360° Body Scanning System for Virtual Reality Research Applications

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Here, we present a low-cost solution to perform the online and realistic representation of users using an array of depth cameras. The system is composed of a cluster of 10 Microsoft Kinect 2 cameras, each one associated to a compact NUC PC to stream live depth & color images to a master PC which reconstructs live the point cloud of the scene and can in particular show the body of users standing in the capture area. A custom geometric calibration procedure allows accurate reconstruction of the different 3D data streams. Despite the inherent limitations of depth cameras, in particular sensor noise, the system provides a convincing representation of the user's body, is not limited by changes in clothing (also during immersion), can capture complex poses and even interactions between two persons or with physical objects. The advantage of using depth cameras over conventional cameras is that little processing is required for dynamic reconstruction of unknown shapes, thus allowing true interactive applications. The resulting live 3D model can be inserted in any virtual environment (e.g. Unity 3D software integration plugin), and can be subject to all usual 3D manipulation and transformations.

From Body Movements to Music - A New Device for Movement Therapies

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A device for music generation through movement is introduced which may be a new tool for therapies especially of persons with disabilities. The system connects fast 3D capturing of acting person(s) with high-resolution 2D images and specialized sound/music modules, which translate the detected movements into sound and musical phrases. In this paper, the main challenges and solutions of the project are presented. Experiments and applications with different groups of patients are described and evaluated.

Describing the Body in New Terms: An Examination of 3D Body-Scanning Technology and Language Use

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The current study examined the effects of 3D body scanning technology and language use. The researchers conducted a qualitative experiment that compared 2D and 3D body scans. Results indicated that the technology changed how participants talked about their bodies. Objectification theory was used to interpret the findings.

TECHNICAL SESSION 10: 3D BODY SCANNING SYSTEMS

3D in the Dark - Full Body Scanning in Infrared

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3D scanning in the spectral range of infrared radiation enables the capturing of high resolution 3D body data in environments with little or no visible light. botspot has developed a hybrid Fullbody Scanner that captures 3D body data in visible light and infrared radiation quickly, without contact and without risk.

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

Size Stream Body Fat Formulas

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Size Stream has developed new formulas for estimating human body fat content via the Size Stream SS20 3D body scanner using machine learning. In addition, a new formula using manual measurements has also been developed.
A significant new finding during this process was that the optimal body measures to predict body fat are different for the lean versus obese ends of the body fat spectrum of subjects. A combined formula has been developed utilizing this knowledge.
These formulas were developed and cross-validated using a diverse set of over 1790 human 3D body scans (of 179 individuals) whose body composition was also measured using a state-of-the-art four-component body composition model. The four-component model (4C) takes into account the human body's four main molecular components: water, fat, bone mineral, and protein/residual. In order to obtain these compartments, estimates of body volume, water content, bone mineral, and total body mass are needed. These variables were provided via air displacement plethysmography (Cosmed BOD POD® Gold Standard), bioimpedance spectroscopy (ImpediMed® SFB7), dual-energy x-ray absorptiometry (GE Lunar Prodigy), and a calibrated body mass scale, respectively. The variables were then inserted into a validated equation (Wang et al. 2002, American Journal of Clinical Nutrition) in order to estimate 4C body fat. A 4C model is considered a true criterion method of body composition assessment. While many body composition assessment methods validate their products using well-respected single-assessment devices (such as DXA), validation using the 4C represents a notable strength of the new Size Stream formulas. Machine learning techniques were utilized to correlate the 3D body scan data to the 4C body composition measurements. The resulting formulas were then cross-validated using two additional test groups of subjects at separate labs.

Development of a 3D Body Database to Improve Measures of Perceptual Male Body Image Distortion

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There are important limitations in the current methodological stimuli being used in perceptual body image research among men, including a reliance on unrealistic images, a lack of biometric validity, and little consideration of the sexual dimorphism of human body composition. This research seeks to address this critical ‘stimulus problem’ through the development of a large database of 3D body scans

and body composition measurements. The aim of this study is to investigate the relationship between body shape and composition, as well as how this varies within distinct body mass index (BMI) categories. Over 170 adult males have been recruited through staff and students at the University of Lincoln and from the general population. Principal component analysis and partial least squares regression are being used to characterise the statistical mapping between 3D male body shape changes and body composition. These statistical models will then allow for the development of a range of photorealistic, biometrically accurate, calibrated 3D male avatars, with future applications in both healthcare and research contexts.

A Motion Capture System for Sport Performance
Analysis Based on Inexpensive RGB-D Sensors

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Motion capture for gesture and performance analysis in sports usually requires tracking of several anatomical landmarks with high spatial accuracy and sampling frequency. In addition, a model of the outer surface of the body can also be useful, e.g. for aerodynamic studies. In this context, we developed a motion capture system based on four inexpensive commercial RGB-D cameras. Our system produces both skeletal poses and 3D meshes of moving human bodies at high frequency with good accuracy.

TECHNICAL SESSION 12: 3D BODY TECHNOLOGY FOR APPAREL III

Working Group Progress for IEEE P3141 - Standard for 3D Body Processing, 2018-2019

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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 addresses in 2020. During 2019, the working group published two white papers focused on File Formats and Communication, Security and Privacy (CSP). The group conducted Phase 1 and 2 of a comparative study of full body using different anthropometric measuring methods including traditional and digital (including phone apps).

Garment Fit: Where Do We Stand?

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The paper describes the general understandings of the concept of comfort and its various components described in the literature. There is given an insight into garment fit problems and existing evaluation methods. The study aims to explain the importance of the anthropometry and the impact of its change and development on the improvement of garment fit provision. The possibilities and benefits of using 3D body scanning technologies in anthropometric studies are observed to explain options to improve the garment sizing and fit evaluation processes. The possibilities provided by modern computer-aided 3D design systems for development and analyzing clothing products are considered. The study includes examples of 3D scanning and virtual prototyping capabilities for assessing the fit and appearance of clothing, highlighting the shortcomings that hamper research into the interaction between the human body and clothing.

3D Body Scanning in the Apparel Industry: Do We Really Know Where We Are Heading?

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This paper through - the Diffusion of Innovation Model - shows that while 3D Body Scanning brings some refining and improvements of existing methods, it does not introduce new concepts that depart from traditional retail practices. 3D Body Scanning is - potentially - a powerful way of approaching size and fit in apparel and one that presents novel opportunities. Yet, despite the advantages that this technology offers, and the many initiatives that have taken place, 3D Body Scanning has not reached its full potential and has failed to produce the expected results held by many stakeholders. Stakeholders must increase collaboration to realise 3D Body Scanning's relative advantage. Much of the potential has, however, been promoted by distinct organisations that are biases about how the diverse processes and structures will work together, whilst focussing on profit from their own incremental IP. In this paper we elicit 3D Body Scanning's fundamental concepts, and its central goal to provide 'glue' needed to create an innovation. We offer further implications for researchers and policymakers about expecting and managing trends in technology.

Novel Methods to Drive Pattern Engineering through and for Enhanced Use of 3D Technologies

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Key obstacles to apparel digitization, frequently and symptomatically observed as limitations within 3D technologies, can be summarized as a lack of theory to quantify body shape and garment ease. Whether discussing garment fit on parametric avatars, automated virtual garment design, mass garment customization, improved garment sizing, or accurate size prediction, apparel digitization has repeatedly been hindered by a lack of theory linking the garment and its shaping requirements to the human form. This is because neither 1D (tape measure) dimensions nor a 3D flattened polygon mesh can quantify body shape with respect to developing garment patterns conducive to apparel manufacturing.

While novel pattern-engineering theory offers body-to-pattern guidance to isolate ease and body shape dimensions, acquiring the required measurements (outside the scope of both ISO boundaries and current measurement extraction software) has proven prohibitive. To prove scan-to-pattern digital viability a study explored the potential for updated measurement extraction software to access underutilized body scan data to drive Clone Block® body-to-pattern theory. Solidworks 3D software was used to manually extract measurements from a body scan and Intelligent Shaping® software was used for automated Clone Block® pattern development. The suitability of the measurements for supporting body-to-pattern theory was then tested based on the ability of the resulting pattern to hug body morphology while maintaining horizontal and vertical fabric grain.

The results of the study indicate automated measurement acquisition to drive Clone Block® shaping methodologies for scan-to-pattern automation is feasible. Based on the premise that garment fit is the result of fit-reality (body shape) plus fit-preference (ease), this study is significant in offering a means by which underutilized scanned body data may be accessed to quantify body shape and ease. Further study should confirm that updated measurement extraction software can automate the retrieval of measurement data and the Clone Block® scan-to-pattern methods (used extensively in a bespoke environment) work on an extended range of body shapes including bodies with dysmorphia. Discussions surrounding ease distribution for body shape should also be studied for foundational mathematical fit-preference and ease theory.

How the U.S. Sport Performance Apparel Industry Sizes Up to Female Plus Bodies

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In the United States, about 68% of the female population is greater than a size 14, or plus size. This demographic represents a $21.4 billion industry. Over the last five years, there has been a movement in the U.S. sport performance apparel industry to manufacture products for this body type, which historically has not been considered "athletic." As there is a lack of accessible measurements and sizing standardization for plus sizes, companies have developed their own unique systems, often

graded from existing “sample sizes” (often a size small 4/6 or medium 8/10) or developed from old plus size standards (e.g., ASTM). As a result, plus size products in the U.S are inconsistently and unreliably sized. This challenge not only affects consumer satisfaction, but it also affects retailers and the environment. As an example, retailers scrap more than 25% of their returns, which can contribute to over five billion pounds in landfill each year. The intent of this pilot study was to understand how well a sample of plus size bodies fit into the top three U.S. sport performance apparel companies' size charts. Sixty-five 3D body scans of plus size women, who self-identified as size 18W, were analyzed to determine how their chest/bust, waist and hip measures compared to the top three companies' sizing schemes. The companies included Nike, Adidas and Under Armour. Findings established that there are opportunities to: initiate a larger study to understand a more comprehensive set of bodies/measures, improve grading and size charts, develop relevant dress forms and product creation for this evolving demographic.

TECHNICAL SESSION 13: 3D BODY SCANNING ASSESSMENT & USE

From 3D Body Scan to Finished Product Without Pushing the Button

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We present an approach that makes it possible to fully automate the process from 3D body scan to finished product. This process can be split into (a) the 3D scanning of the person and (b) the processing of the data into a finished product.
We start with focusing on the 3D data acquisition process. The main advantage of automating the 3D scanning is to avoid the need for a scanner operator, which reduces labor costs. This is particularly useful in situations where a fixed scanning booth is placed for a long term at a location where there are considerable peaks and valleys in the number of daily visitors (e.g. theme parks or museums). We achieve this automation by the use of pre-registered RFID wristbands. When a visitor enters the building or park, they receive a blank RFID wristband which they register at a terminal. The registration process collects all the needed data, such as the email address and preferred language for further communication. The visitor can then activate the scanner by simply tapping the wristband to an RFID reader connected to the scanner. Video and audio instructions in the correct language are then automatically played and the visitor is guided through the full scanning process without the need for an operator. It tells them how to behave, such as being correctly positioned, avoid wearing glasses, get hair tight etc.) in order to receive an optimal scan. The visitor will receive an email with a link to his / her 3D scan whenever the processing is ready.
When the data is captured and transformed into a raw digital 3D model, the data needs to be further processed into a finished product. Performing these tasks manually requires specialized knowledge, expensive software and a considerable amount of time. By automating and offering them as a scalable cloud service, the processing time decreases and the solution becomes more cost effective. Our approach allows for offering scan to product conversion by a single API call, while being able to deal with different types scan data, product definitions and special requirements. We achieve this by building easily configurable modules and combine them into suitable pipelines for every specific situation. Modules are for example mesh fixing and thickening, creating a shell, creating 2.5D bas-reliefs, texture unwrapping, color corrections and 2D rendering. Final products are for example digital 3D printable figurines standing on a personalized baseplate, laser engraved 3D crystals, 2.5D wax stamps to seal envelopes and many more.

HOLOFIL - 3D Visualization Front End for Body Scanners

Mrunal GAWADE
HOLOFIL, Amsterdam, The Netherlands

HOLOFIL is a 3D visualization tabletop device that engages user's attention upto 5 times better than a flat screen. It can be used as a front end visualizer for 3D scanning systems to show case the 3D scans for an improved user experience and engagement than the traditional mediums such as flat screens. HOLOFIL is portable, affordable, Android based and creates good value for promotions, branding, education, and training to create that wow factor. It works in non-interactive, interactive and real time streaming mode.

3D Face Analysis vs Applications: Studies and Perspectives

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In the present scenario biometry is becoming a very important issue. Starting from the marketing domain where business man are trying to capture people emotions when they buy a product in the supermarket, till arriving to border security, or event security, where companies are trying to propose automatic solutions able to identify critical situations, and be sure that the identification of the person is reliable, also in presence of camouflages, the involvement of biometry is growing up very quickly, involving finger prints, iris recognition, voice recognition but especially human face analysis. In this specific domain many improvements have been done, due to the fact that face has many distinctive issues, and interesting results have been obtained, especially working with 3D models, rather than simple 2D images more fragile for the significant influence due to the working conditions, that are able to provide more reliable results and solve problems connected also with people age. Starting from these challenges, from the more easy availability of low cost 3D sensors, also located on commercial mobile devices, and from the experience acquired in the Politecnico di Torino 3D Lab (www.3dlab.polito.it), this papers wants to presents a review of the main outcomes coming from 3D face morphometric applications, providing a systematic synthesis of the different available methods and approaches in order to guide potential users in simply identifying the most suitable solution and technology in relation to the specific application and working conditions, providing some first issues on strengths and weaknesses.

Reliability of Measuring Morphology of the Paediatric Foot
Using the Artec Eva Hand Held Scanner

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The growth and development of the paediatric foot throughout childhood is poorly understood. To inform theory that underpins clinical practice, there is a clear need to revisit our understanding of how the foot develops. Hand-held 3-D scanners provide portability and allow researchers to collect data about foot development in the children’s natural environment. However, there are methodological challenges to consider: scanning the plantar surface in a static weight-bearing position, the children’s ability to remain static for the duration of the scanning and software capabilities. The aim of this study was to determine the reliability of using a hand-held scanner to capture children’s foot shape and size. For this study, 15 children aged two years (Group 1: n=5), five years (Group 2: n=5) and seven years (Group 3: n=5) were recruited. Children stood barefoot in a comfortable bipedal stance, on a Perspex platform of 550mm height. Their feet were scanned three times, including the plantar surface through the platform, using the Artec Eva (Artec Group, Luxembourg, Luxembourg) hand held scanner. Post-processing of the scans was performed in Artec Studio 12 (Artec Group, Luxembourg, Luxembourg). Data processing and statistical analysis of 3D data were performed in Matlab R2018a (The Mathworks, Natuck, USA), while linear measures were calculated in Foot3D (INESCOP, Elda, Spain). To assess reliability, root mean square error (RMSE) of 11 linear measurements, mesh deviations (Euclidean distances) of the 3D coordinates of corresponding vertices (after rigid registration of the meshes) and RMSE for shape-index (SI) and curvedness (CU) were calculated.
Results showed good reliability for eight linear measures with an average RMSE of 1.14mm across groups and all measures (RMSE range: 0.19mm - 3.73mm). Three measures exceeded a RMSE of 2mm, two of which were from Group 1. Mesh deviation results showed good reliability in the older children (Group 2: deviations under 0.5mm: 73.03%, under 1mm: 94.12%, Group 3: deviations under 0.5mm: 68.82%, under 1mm: 96.20%), but not in the youngest group (deviations under 0.5mm: 53.19%, under 1mm: 85.83%). The heat maps of mesh deviations across the foot surface, indicate increasing mesh deviations in the toe and ankle area from Group 3 to Group 2, while Group 1 also had higher than 1mm deviations on the lateral and dorsal surface of the foot. Root mean square error for curvedness and shape-index for the 3 scans of the same foot decreased with increasing age, but in general indicated good reliability.
The results of this study demonstrated that the hand-held scanner was reliable for capturing children’s 3D foot shape, however there were methodological issues in the youngest group. In Group 1, the mesh deviation results demonstrated lower reliability in four distinct areas (toes, lateral and dorsal surface and ankle). The higher mesh deviations were a result of these children being unable to stand still for the duration of the scan and having a more variable stance on the platform between scans. The fact that the RMSE of two linear measures exceeded 2mm in the youngest group also supported this

proposal. Future studies employing hand held 3D scanners should consider these results and handle 3D scanning data of two years old children with caution.

TECHNICAL SESSION 14: 3D BODY TECHNOLOGY FOR APPAREL IV

Functional Body Measurements - Motion-Oriented 3D Analysis of Body Measurements

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The balancing act between freedom of movement, functionality and fashion orientated fit for different target groups poses new complex challenges on the manufacturers of work and sportswear during development and sales.
Anthropometric data is used for clothing design, PPE, workspaces and human-machine interfaces. Two different sizing systems are used for this: size charts and ergonomic standards. Size charts are the base for the clothing industry, although these cannot cover the functional requirements for workwear and protective clothing. The variability of body measurements during movement is partially noted in the Ergonomic-standard, but these are nonrelated to the clothing sizes. A standard that correlates the sizes with the functional movement of the body while working was not available until now.
The variability of body measurements was investigated in the research project “functional measurements”. In this process the focus was laid on the 3D-analysis of body measurements of women and men in different postures through the 3D-BodyScanner. The precise results of this are: 93 3D-Scans of men and women in different postures, description of bodily variance while in motion, size charts “functional measurements” for men and women, as well as recommendations for optimized allocation of individual customer measurements for standard sizes. The project results can be used for pattern development and fit optimization for clothing with a high ergonomic comfort.

Method to Capture and Analyze the Waist-Hip-Thigh Body Region of Seated-Standing 3D Scans

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The purpose of this research was to explore new methods of 3D scanning, body postures, and landmarking techniques to complete in-depth analyses of skin deformation, measurement change, and shape change of the waist-hip-thigh region of the body. There is a need to develop and test new integrated measurement analyses using 1D, 2D, and 3D data to quantify how and where the body is changing in different postures. An integrated approach was taken to select the appropriate 3D scanning technology, develop a landmarking method, and position the body to analyze the waist-hip-thigh region. A convenience sample of 11 women participated in the pilot study, ranging in age from 41-73. Using a quadrant landmarking technique, the body was divided into sections to locally analyze 1D and 2D measurements, while conducting volume and curve analysis to aid our understanding of shape change. Local percent change of each circumference was significant, and the data across the various measurements captured the expansion and shrinking of the body. Additionally, the 1D, 2D, and 3D analysis of the models shows the body deforming differently based on participant size, indicating this type of data could be critical for improved size system creation. The results from the extraction of curves represents exciting frontiers in 3D shape research and in the future will enable shape to be more easily incorporated into wearable garments. This data can improve the development of materials, trims, pattern design, and sizing systems. New 3D scanning methods to quantify diverse bodies can improve a company’s competitive advantage through enhanced product fit and inclusive, quality design for all.

The Detection of the Upper Boundary of Breasts Using 4D Scanning Technology

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Defining the boundary of female breasts is an unavoidable and very essential step before estimating the volume or surface area of the breast. Anthropometric measurements such as these are critical to the understanding of breast shape and the development of bra products. However, a non-contact method that accurately detects the boundary between breasts and chest wall, for breasts evaluated in

the upright body position, has not been reported before. In this study, with the help of 4D body scanning and taking advantage of the time delay in the vertical displacement between the breasts and the chest wall during physical activity, we 4D-scanned 26 female participants using the Temporal 3dMD system and proposed a method to visualize the amount of variability for the relative displacement in the vertical direction, to facilitate the definition of the upper boundary of breasts. By viewing each breast as a cone or hemisphere, and processing the scan through vertical slicing, we were able to make all the scans having the same number of points (7200= 180×40. There were 40 vertical slices in total, and on each slice, there was one point located at every other degree from -180° to 180°) sorted in the exact same order. After proper alignment, we calculated the z-coordinate difference between a scan captured while the participant was running (there were nine dynamic scans that formed a gait cycle) and the corresponding scan of the same participant captured in static standing (the static scan). Then we were able to calculate the standard deviation (SD) value of the z-coordinate differences (i.e. the relative vertical displacements) across the nine dynamic scans. Heat maps were then created with the SD values mapped onto the 3D surface of the static scan and presented by gradient colors. This study is one of the first comprehensive studies that investigate the vertical displacement and the shape deformation of breasts during running using 4D scanning technology. Ultimately, the method and results can increase the understanding of breast kinematics, and benefit the product design of bras, especially for sports bras.

Trends in Breast Measurements of Unilateral Breast Reconstruction Patients to Inform Bra Design

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Breast reconstruction patients face unique challenges in finding a properly fitting bra after breast surgery, leading to decreased bra comfort and psychosocial functioning. In addition to considerations such as location of seams and choice of fabric, identifying trends in how breast shape and symmetry measurements change between native breasts and reconstructed breasts may help inform bra design for reconstruction patients. We have previously developed a correspondence system between bra measurements and clinical breast measurements used by reconstructive surgeons. The selected measurements describe the size and projection of the breasts as well as their relative location on the torso as captured by clinical photographs. In this study, we explore how reconstruction changes breast measurements pertinent to bra design by analyzing 3D surface torso images of 15 unilateral implant-based breast reconstruction patients before and after their reconstruction surgery. Using custom software developed at University of Houston, two researchers measured several breast properties on a 3D surface torso image taken before mastectomy and on another image taken after each patient's final implants had been placed. 14 of the 15 patients had completed their reconstruction surgeries by the time that the second image was taken. We compared the differences in measurements between the pre-mastectomy image and post-mastectomy and reconstruction image for both breasts separately, as well as change in right-left symmetry of the measurements between the pre- and post- images. 14 out of the 15 patients had a revision surgery performed on the contralateral breast to enhance post-reconstruction symmetry. The three most affected measurements between native breasts and breasts reconstructed after mastectomy were the sternal notch to most projecting point, lateral point to most projecting point, and mid-clavicle to transition point to most projecting point. These changes can be attributed to the size and shape of the implants used to compensate for the removal of native breast tissue, which change the fundamental footprint and curvature of the breast. Asymmetry between the breasts also increased after breast cancer treatment despite reconstruction and contralateral revision procedures. These measurements can be used to inform bra designers of what adjustments may be needed to bra patterns to improve fit for reconstruction patients.

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