Book of Abstracts

4th International Conference on

3D Body Scanning Technologies

Long Beach CA, USA, 19-20 November 2013

Editor and Organizer

Hometrica Consulting - Dr. Nicola D'Apuzzo
Switzerland
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TABLE OF CONTENTS

INTRODUCTION

Conference director's message #00

Nicola D'APUZZO
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The 4th International Conference and Exhibition on 3D Body Scanning Technologies takes place from 19 to 20 November 2013, in Long Beach, California, USA.
The first three international conferences of 2010, 2011 and 2012 were all largely attended with over 200 participants from different countries, different technical fields and different industries.
The rich technical programs of the three events included a wide variety of works related to applications, developments and research on 3D body scanning from all over the world.
The conferences were accompanied by parallel exhibitions featuring live demonstrations of 3D body scanning equipment and solutions. Various manufacturers had chosen our events for presenting and announcing world premieres.
The past three events were also the occasions where births of new collaborations took place, as for example 3dmD (USA) and Max Plank Institute (Germany), TC2 (USA) and SpaceVision (Japan), UCS (Slovenia) and ElinVision (Estonia).
With the success of the 3rd event of 2012, the conference confirmed again to be the most important international event for the sector of 3D body scanning technology. With this forth event of 2013, we continue the role as the world leading technical platform dedicated to these specific fields.
This book of abstract is divided in sections according to the conference's technical program and it includes the abstracts of the papers published in the proceedings of the conference. The corresponding papers can be easily found in the proceedings by the paper id number indicated in the table of contents and by each abstract's title.

OPENING SESSION

3D Body Scanning, Past and Future #64

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New technology is valued for one of two reasons: 1) it enables us to do something better or cheaper or 2) it enables us to do something we couldn’t do before. Many people still value 3-D scanning for the first reason, because they think it enables us to gather 1-D measurements better, faster or cheaper. In 1996 when recruiting partners for the first whole body 3-D scanning survey we thought the 3-D scanners would automatically produce more accurate, consistent and repeatable 1-D measurements than manual measurers do. While we found that 3-D scanners can produce highly accurate, consistent and repeatable 1-D measurements for point-to-point distances, it has become clear they can’t do that without an expert pre-marking measurement locations. In addition, for circumferences, such as waist circumference, hip circumference, and vertical trunk circumference, the tape measure is still superior to the 3-D scanner. However, 3-D scanners are much more valuable than just alternative 1-D measuring tools. 3-D enables us to do things we can’t do with 1-D data, (the second reason why new technology is valued.) 3-D provides shape, contour, volume, location, comparative locations over time or under different conditions, (such as fitting versus not fitting) or between two people, etc. 3-D provides capability essential to: true-to-life dynamic human modeling for design, injury prediction, fit quantification, situational visualization and more. Some people might even argue that if you have 3-D you don’t need 1- D, but 1-D data are easy to store, search and use for simple categorization using tools readily available to most people. Therefore the two tools each provide different capabilities and are even more useful together. In other words, 1-D can be used to make 3-D more accessible and useful to the common person. This presentation reviews the evolution of anthropometry technology, the lessons learned, the goals and aims of the research and proposes a vision of the future for the science of anthropometry that could change the way human-worn or inhabited products are designed and produced.

TECHNICAL SESSION 1: MEDICAL SCANNING SYSTEMS

Breast Volume Calculation Using a Low-Cost Scanning System #28

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Breast volume has been identified as a key metric in assessing patients for reconstructive surgery.
Scanning systems have measured breast volume but they have tended to rely on expensive hardware and software. This paper discusses the development and assessment of an algorithm capable of calculating breast volume from 3D point data. A mannequin was scanned (using a custom, Kinect based scanning system) with one of two breast prostheses attached – 400g or 600 g. Each scan was assessed by three independent operators: seven anatomical points were identified representing the boundary of the breast region, which was then isolated. A Coons patch was used to represent the invisible chest surface lying below the breast tissue. A trapezium rule based approach was used to calculate the volume of the enclosed region between the breast and chest surfaces. Breast volume was over-estimated by 130 cc with the 400 g prosthesis (30.3%) and 206 cc (33.3%) with the 600 g prosthesis, suggesting positive proportional bias. Average reliability was ± 59.7 cc for the 400 g prosthesis (13.9%) and ± 34.7 cc for the 600 g prosthesis (5.6%) – approaching the levels required to differentiate between implant sizes (25 -50 cc). Future work will focus on refining the hardware and software of this scanning system – minimising proportional basis and maximising reliability of measurement.

Facial Overlay Analysis - Combined Repositioning and Computer Alignment #18

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Differential comparison of two- and three-dimensional images require aligned subjects in order to discern small structural and contour changes to the facial area. Overlay of subject images at different times and dates is reliant on the ability to precisely align the subject during each clinical visit. The alignment device must be capable of providing sufficient adjustment to accommodate a wide variety of subject body and facial characteristics, and be re-adjusted rapidly and accurately. Changes observed in facial contour are valuable in the analysis of topical cosmetic formulations and in demonstrating efficacy of anti-aging, sagging, and lifting interventions.
Stereotactic devices are intended to maintain an orientation of the head for a limited period of time, but not for repeated use. Those employed for surgery are required to prevent movement, but disregard subject imaging. In most imaging alignment devices, restraining alignments encumber the face and neck preventing full image collection by obstruction of view or distortion of facial features. A device to reproducibly position the face and head was previously reported and has been utilized in third party clinical studies. Clinical results have shown positive alignments of subjects, but also identified operational variability associated with subject seating, parameter setting, imaging, training, and subject compliance. The device provided a novel alignment process including, gross subject alignment, fine subject alignment, and direction-of-gaze.
At the baseline clinical visit, a “subject fitting” defines the subject orientation and device parameters utilized during subsequent imaging sessions. Head touch points at the back and top of the head are maintained by the subject and allow undistorted full facial imaging and analysis of the face, jaw, and neck regions. Subject specific device parameters are maintained within 0.1- 0.2 mm. The alignment system includes staff and subject education and training. Subject cooperation and staff oversight are critical in the realignment procedures. Integrated positioning devices reseat the subject body, co-locate the head, and maintain the direction-of-gaze of the subject. Overlay comparison results for 3D imaging have indicated excellent correlation of the entire facial region. Combinations of 3D contour and 2D image overlays were used to evaluate subject profile changes and illustrate locations of facial lifting associated with topical treatments.
Facial overlay routines usually attempt to co-locate the entire facial area for comparison. Full face surface analysis does not separate topically treated and reference regions.
Consequently, changes in treated regions are trivialized through averaging the overall facial evaluation. Side-by-side comparison of the inclusive/exclusive region processes demonstrates the need to require separation of treated and non-treated surfaces. Utilizing only reference regions, the treated regions of the face are excluded from the overlay comparison and are considered “experimental surfaces”. Only stable untreated facial regions are considered as reference surfaces within the algorithm.
The reference technique maintains the facial reference locations, and allows other non-aligned surfaces to be

identified. Movements associated with the neck, upper torso, and shoulders between clinical visits are identified, as well as small facial gestures that might go un-noticed in standard 2D image comparisons. Identification of these movements permits modification of the system and protocol while still capturing full 3D facial contour.

A Two-Picture Acquisition System for 3D Geometry and Light Reflection Modeling of Faces for Cosmetic Applications #61

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Objectifying the visual effects of cosmetic products is a major concern for both manufacturers and consumers. One of the most complex effects of cosmetic products is the transparent aspect of the top layers of the skin, called translucency. Most evaluation methods of this phenomenon are still very subjective due to the complex visual quantification. For evaluating the effects of cosmetic products on skin translucency, we have developed an acquisition system to recover facial geometry and translucency coefficients. The equipment is designed to be low-cost and portable, and our reconstruction procedure needs only two photographs. The algorithm for 3D reconstruction uses one photograph of the face of a human subject on which was projected colored structured light to extract a 3D surface. An image-based approach deduces an RGB translucency value for a skin patch from a unique non-calibrated photograph. The proposed system was proven robust by means of experimentations conducted on 20 subjects and three different cosmetic products. We show that an image-based evaluation procedure is sufficient to consistently differentiate translucent effects of a range of cosmetics on a same skin, even from a unique non-calibrated image. The extracted parameters can be used for assessment of the effect of a product or for simulating this effect on a face.

The Potential for Dense Dynamic 4D Surface Capture - Illustrated with Actual Case Studies #08

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Recent developments in 3D surface imaging technology have opened up the possibility of capturing very granular models of skin and soft tissue behavior in human subjects. In the past studies of facial or body movement have entailed the use of optical markers or very crude attempts to fit video photographic sequences to sparse deformable models. While such techniques have been adequate for the special effects industry they are of little value to medical and anthropometric studies where the value is in the detail and sub-millimeter moves may have significance. Rather than just seeing a general limb movement we can record the muscles rippling under the skin. Not only is the capture and rendering of this information challenging but new analytical techniques have to be developed which allow movement data to be presented in a manner where patterns can be identified and numerated to support the investigations and draw appropriate conclusions.

3dMD was the first company to develop a dynamic dense surface 3D capture device with first system being installed at Cardiff University in 2005. Over the past 8 years 3dMD has worked closely with Cardiff and several other universities to not only develop the capture, rendering and optical tracking technology but establish research and evaluation protocols to use this information to further research and understanding of external dynamics of human form. Many validated academic papers have already been reviewed and published for clinical, anthropometric and behavior studies.

This talk will chart history of this project and explain why other technologies have been unable to provide definitive results. Detail and guidance will be given on the capture protocols and project/session workflow and how such technology can be applied in everyday situations. Most importantly the lecture will be illustrated with actual case studies many of which have never been seen before publically. These will include cases looking in facial expression, muscle and anatomic movement, inference of internal dynamics based on soft tissue deformation and the sequence of two people interacting.

Finally the talk will indicate the areas where dynamic 3D will be used in the future both as a measurement tool in its own right as well as a calibration for low cost movement sensors. These will include behavioral, body dynamics and clinical uses. One thing is clear there is much to be discovered and understood by applying this technology and surprising conclusions can be drawn quite rapidly because the data is so complete.

TECHNICAL SESSION 2: BODY SCANNING FOR APPAREL I

Effectiveness of 3D Scanning in Establishing Sideseam Placement for Pattern Design #65

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As woven garments are cut from flat pieces of cloth, pattern cutting methods must create flat 2D shapes that are constructed to form 3D garments that fit a particular body shape. The placement of sideseams represents a key division of the pattern where the front and back portions of a garment relating to a particular body measurement are distributed to create a balanced garment. During most pattern creation methods the distribution of the measurement into back and front arcs is proportionally determined by the author, however body scanning provides new opportunities to understand the body and derive these arcs during the measurement process. TC2 measurement software provides the facility to automatically derive arcs based on non-disclosed divisions of the body along a vertical plane. This research tests the automated division of key circumferences into arcs using the TC2 software, against methods guided by practitioner experience and placed using non-automated 3D software. Focusing on circumferences of the bust, waist and hip, analysis of the arcs derived by the scanner from a number of standard female body forms and 10 scans of female subjects, will be tested against those determined by a panel of experts. These methods form the basis for an understanding of how circumference division can be automated and allow for the testing of these methods on a variety of different scans and the comparison of the arcs against those proposed or applied in standard industry practice. It will be possible to see how closely these methods match or contrast with these imposed systems. This exploration provides a clear link to body pattern relationships and provides a foundation from which to advance mass customization utilizing body scanning technology and automated arc definition.

Applied Body Scanning Technology for the Extreme Sports Apparel #56

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Whole body 3D scanning is an important tool for collecting measurement data for the custom fit apparel markets. The ability to take measurements en mass for a specific group such as the uniforms for hotels and military is quickly being adopted. Once those measurements are captured for the group, the data can be used for size prediction of standard sizes or for custom fit orders.

The challenge for custom fit centers on the product types being offered. Defining the product with target market, technical design, measurements and parametric modeling in mind will greatly increase the success of servicing the custom fit business.

Stacy Holt, an Apparel Engineer with over 25 years' experience in apparel manufacturing and product development will explore how these challenges are overcome with the use of the latest apparel CAD technologies. Optitex's PDS, Virtual Prototyping and Modulate software will be used to demonstrate the process. Beyond Clothing Ltd, a manufacturer of extreme sports and mission apparel will assist with live subjects and styles.

3D virtual-Try-On: The Avatar at Center Stage #19

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Being the true clones of real humans – regardless if they have been body-scanned or built from scratch –, 3D avatars are getting more attention in the fashion industry, thanks to the development of virtual try-on. With increased confidence in the virtual representation of reality (human body, garment and fabrics), fashion designers and pattern makers now work collaboratively. The 3D representation of a garment on a 3D avatar is now the base of discussion between professionals with different technical backgrounds and vocabulary – before a single piece of fabric is cut and assembled! Thanks to body-scanning capabilities, the numerous postures of a 3D avatar can facilitate the development of styles and collections. A demanding consumer can now literally give his/her own avatar – his/her body-scan – for apparel professionals to adjust garments to his/her own morphology. The 3D avatar is at center stage, boosting virtual try-ons. The lecturer will present how the 3D representation of postures, garment pieces, and fabrics are crucial in making informed decisions, before a garment is produced. Both ready-to-wear and made-to-measure market segments will benefit from a 3D-based enhanced collaboration between fashion designers and pattern makers.

Fitting Simulation Evaluated on Self Body Scanned and Programmed Avatars #09

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Avatars and virtual fitting simulations provide an opportunity for designers to view designs and fit on the body prior to construction. Additionally, computer programs now offer a selection of avatars. This study explores and evaluates a fitting simulation using a custom avatar developed through self body scanning and a pre-programmed avatar selected from 3D CAD virtual prototyping software. For the fitting simulation, a convenience sample of ten volunteers developed their own custom avatar using the Kinect 3D Body Scanning system and then selected an existing computer avatar based on their measurements from the prototyping software, Optitex. Pattern designs were then selected from the software and fitted on both avatars. Using select criteria, three design professionals assessed the fit of the designs on each avatar and compared the results. Findings indicate differences in the appearance and aesthetics of the avatars, realistic reflection of individual differences in body types and accuracy of the relationship of the garment to the body. Although the programmed avatar offers a more refined aesthetically pleasing body image, the custom self body scanned avatar provides more realistic body proportions, fabric drape and fit.

An Exploratory Study of Virtual Fit Testing Using 3D Virtual Fit Models and Garment Simulation Technology in Technical Design #10

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The use of Three-Dimensional (3D) body scanning technology in the area of technical apparel design has begun to receive more attention and be implemented in the industry over the recent decade. The purpose of this study was to observe the effectiveness of 3D virtual fit testing processes using body scans and garment simulation technology and to identify the areas of challenge in the process of 3D virtual fit and pattern manipulation. In this study, two fit models were recruited based on ASTM measurements for Misses and Women's plus size. One Misses size 8 model represented the standard size as a control, and the other model was Women's plus-sized 16. Fit models were scanned and created into 3D virtual models (VM) using a [TC]2 body scanner. Two types of garments were selected as test garments: a basic unlined bodice and pants. Both garments were made from a medium-weight cotton woven fabric. These garments were selected for their representations of basic garment style, and there are definite expectations regarding the fit. Three advanced undergraduate apparel design students were selected and trained. Each participant manipulated the patterns to fit each virtual model (VM). The virtual fit testing and fit correction were recorded using Camtasia screen recording software. Then, the actual garments were made and tested on live models. Live fit models evaluated the comfort and fit of the garments. The results indicated that participants spent more time on size 16 than size 8, and the bodice took twice as much time as the pants. Based on the size 8 fit model evaluation, the least satisfying fit was found in the neckline, crotch, and pant hem. This may be due to the difficulty in determining fitting ease using 3D simulation. The results of the size 16 live fit test showed that poor fit was found in the underarm, neckline, abdomen, buttocks, hip girth, and thigh. More fit problems on the pants were found in size 16. This may be due to lack of knowledge among participants concerning plus-size pants fit and pattern shape. This study revealed that fit ease and certain areas of greater body curve should be further tested on the live fit model for accuracy.

Use of 3D Body Scanner Data in Digital Tailoring #69

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Precise measurements are the key for making digitally tailored garments. Therefore it is necessary to have measurement defined by the measurement extraction profile which would correspond to apparel basic block construction. A block is a foundation pattern constructed to fit a specific human. A block should be defined as formulas to the CAD/CAM system (Gemini) or altered by CAD/CAM systems (Lectra, Optitec, Gerber, etc) to fit an individual figure using personal measurements.
The data captured by body scanner can be very precise depending on the technology (white-light, infrared depth sensor, etc) and the amount of detectors (lasers/sensors/lights) used. The precision of measurements obtained depends on how exactly the body scanner detects the body surface and how good is the measurement extraction profile. At the moment, there can happen that even two different versions of scanners from the same

company can produce results with 3-4cm difference in knee circumference (depending on the knee circumference).
After considering over 10 000 body scans, I have come to conclusion, that the existing scanners do not detect well enough crotch area (the region of the body where the legs join the torso, and are often considered to include the groin and genitals). Measurement extraction profiles do not allow to map crotch point (the crotch point is the point starting from which the cross-section of the body changes from one circle to two circles) as it is constructed in the persons block where the legs join together and the bottom of the crotch defines one end of the inseam.
We should have a standardized "human" prototype as a tool to compare results produced by different scanners in order to secure the precision of the body scanner data and measurement extraction profiles.

TECHNICAL SESSION 3: MEDICAL APPLICATIONS I

Virtobot - A Robot System for Optical 3D Scanning in Forensic Medicine #25

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In this article, we present the second prototype of a robotic system, for use in forensic medicine. Among others, the system is able to perform automated whole body surface and wound documentations by using digital close-range photogrammetry and optical 3D surface scanning. Based on the 3D data collected, analysis and reconstruction of forensically relevant events, such as traffic accidents, criminal assaults or homicides can be performed. The newly applied high-tech methods can provide new knowledge about a case, compared to traditional methods.
The purpose of the Virtobot project is to develop a robot prototype that provides fast and accurate, 3D measurement capabilities for documenting external injuries of corpses in three-dimensions and color, supporting forensic investigations.
The system is routinely used at our institute for surface documentation, resulting in 24 surface documentations over the course of 11 months. The main focus was on streamlining the workflow and increasing the level of automation, reducing the scanning times from approximately 40 to 11 minutes. This makes the Virtobot a potentially valuable tool for case documentation in the field of virtual autopsy.

Does the "Rule of Nines" Apply to Morbidly Obese Burn Victims? A Post-Bariatric Surgery Longitudinal Follow-up to the Original Patient Data Set #52

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Background. The Rule of Nines is a method of estimating the extent of body surface that has been burned in an adult, dividing the body into sections or multiples of 9 percent. This assumes a "normal" adult shape. The shape of the bariatric subject is exaggerated. Is the Rule of Nines applicable to the bariatric subject?
Methods. 200 bariatric patients of various shapes and sizes were scanned using a 3D whole body scanning device. The scanner captured an accurate, measurable 3D body model. Software was programmed to determine the surface area of the arms, torso and legs. Height, weight, BMI, gender and body shape were tabulated. A statistical analysis was performed.
Results. The Rule of Nines is a poor approximation and not applicable for the bariatric patient. Average Torso Surface Area was 47% compared to 36% for the "normal" shape. Arms Surface Area was 7% compared to 9%. Legs Surface Area was 15% compared to 18%. Android shapes had an Average Torso Surface Area of 49%. Gynecoid shapes had an Average Torso Surface of 43% Analysis was further divided by gender.
Conclusion. It appears a "Rule of Sevens" is a more appropriate method for estimating the extent of body surface for the bariatric subject, a significant 27% difference from the Rule of Nines. BMI, height and weight appear to have little influence on this relationship. This "Rule of Sevens" can be a useful discovery to assist treating severely burned bariatric adults.

Computation of Breast Ptosis from 3D Scans of Torso #33

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Ptosis is an important morphological parameter for characterizing breast aesthetics and is frequently assessed before breast surgery. It refers to the extent to which the nipple is lower than the inframammary fold (the contour along which the inferior part of the breast attaches to the chest wall). Current clinical assessment of ptosis involves qualitative visualization by observers, which is subject to inter- and intra-observer variability. Alternatively, ptosis can be measured anthropometrically directly by manual measurements from the patient or indirectly from manual or computerized measurements on clinical photographs. Although functional, these methods are subject to operator bias and can be practically limiting. As stereophotography is now finding its niche in clinical breast surgery, in this study we investigated and evaluated the utility of three-dimensional (3D) features such as surface curvature, coronal projection and surface normal for the assessment of breast ptosis using 3D scans of the torso. Experimental results suggest that 3D features are successful for objectively categorizing breast ptosis with high accuracy and precision.

TECHNICAL SESSION 4: BODY MODELING & AVATARS

Methodology for Construction of a T-Pose 3D Human Model #32

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Restrictions in the scan volume of typical 3D body scanners, such as the 3dMD Body Scanning System, have imposed severe limitations in their use for creation of 3D models for the purposes of human animation. For these purposes, the ideal pose is to have the human subject stand with the feet shoulder-width apart and arms held completely horizontal at the shoulders (known as a T-Pose). This pose, however, is difficult to capture, especially for taller individuals whose arms may not fit within the capture volume. As a result, scans are typically collected with arms down towards the body rather than parallel to the ground. With these scans, animators are forced to choose between creating a completely fictional human (e.g. an artist's rendition) or painstakingly modifying the scan to arrange the underlying 'bones' into the proper T-Pose. One type of 3D mesh file utilizes a process known as vertex mapped texturing, in which an RGB color value is assigned to each vertex in the mesh. Another method is known as texture mapping, in which a separate texture file is created that 'wraps around' a geometric mesh. This process usually leads to visually pleasing scans; however, some difficulties arise with these files. For instance, the texture mapping process makes it impossible to merge scan files together while retaining color/texture information. This paper explores a method of generating 3D mesh models in two major scan formats, through the use of merging multiple scans and a series of software operations to reduce the amount of time and effort required by animators/computer graphics professionals.

Parametric Modeling of the Human Body Using Kinect Measurements #21

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Personalized digital human modeling is useful for a wide variety of applications. An obvious interest comes from the entertainment industry, where movies and video games explore the possibilities of this technology. In biomechanics, human modeling assists in the design of person-specific solutions to improve the human well-being and ergonomics. Other applications exist in virtual dressing rooms, human-robot interactions in robotics, etc. Existing technology, although performing well, has the disadvantage of being expensive, immobile, not fully customizable and possibly requiring external body markers. To tackle these issues, this paper presents a modeling technique using the open source software MakeHuman, based on body measurements obtained with Microsoft’s Kinect. The current solution is able to retrieve these measurements when the person is standing in a calibrated scene, this means when the person’s position is known a priori. In order to retrieve the measurement data as a point cloud, and to process this point cloud, the PCL (Point Cloud Library) software is used, leading to

a fully open source implementation. With these tools, solutions for person segmentation, measuring and personalized modeling are proposed. It appears that the current Kinect technology on itself is not very accurate for measuring body sizes. However, this work shows that the Kinect information combined with the MakeHuman modeling tool is valuable. The final model incorporates measures like body height, arm span, hip, waist and chest width, completed with information such as age, gender and weight. Evaluation of the resulting human model shows moderate to good results in modeling body height, hip and waist width, whereas chest width modeling is rather poor due to difficulties in chest width extraction from Kinect images.

ShapeMate: A virtual Tape Measure #67

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We introduce ShapeMate, a framework for human body shape estimation and classification for on-line fashion applications. Given a single image of a subject our framework is able to simultaneously estimate detailed 3D human body shape and compute foreground segmentation with minimal user input. Once the body shape has been estimated, various semantic parameters are extracted for garment size and style recommendation. Preliminary results demonstrate that a single image holds enough information for accurate shape classification.

Bodyhub.com: A Cloud-Based Service for Automatically Creating Highly Accurate Articulated 3D Models from Body Scans #62

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There are many 3D body scans in the world that are not being used because people lack the tools to process them, analyze them, and animate them. When a person is scanned, large portions of their 3D surface shape are captured, but the full scan often suffers from noise and missing data. At best, the scan provides a static snapshot of the person in a single 3D pose. Building on the world-class scan registration technology demonstrated by MPI Director Michael Black during last year's keynote, Body Labs, Inc. will premier a cloud-based service that allows anyone to upload their full body 3D scans to automatically create highly-accurate 3D body models. These models can be both reposed and reshaped, and provide an ideal solution for converting noisy 3D scans or point clouds into a clean, consistent 3D models that can be directly imported into standard CAD/animation software.
Bodyhub.com fits each customer's scans with a single, deformable model that accurately captures the statistics of human pose and shape variation. This fitting process automatically accounts for missing data, and makes it fast and affordable to turn 3D scans into 3D bodies. Once a scan has been converted to a model, its shape and pose can be understood and manipulated. Anatomical measurements can be extracted, and even adjusted, as can the person's 3D pose. By fitting all scans to a common 3D template mesh, Body Labs is also able to extract statistics from a collection of scans, identifying, for example, how specific parts of the body vary in shape across the sampled population. The collection of scans can also be supplemented with 3D bodies created from measurements alone.

TECHNICAL SESSION 5: WORLD ENGINEERING ANTHROPOMETRY RESOURCE I

Sizing up Australia: The Next Step - Summary #36

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This paper describes the development of the methods and scientific parameters for a proposed Australian Body Sizing Survey. It builds on a previous research that established the need for such a survey. The aim of this research was to learn from others' experience and establish methods for planning and conducting a robust national sizing survey that would meet the needs of a broad range of anticipated stakeholders. Two further stages are needed before an Australian Body Sizing Survey can be realised: 1) to identify stakeholders, test the survey design against their needs and finalise the method and scientific parameters and 2) to conduct the Australian Body Sizing Survey by collecting raw data according to the agreed method and scientific parameters.
In this research we sought answers to basic questions, such as: What should an anthropometric survey deliver? What components make it useful? Will it work? Will it be fit for purpose? The research established the

characteristics of a good measurement with examples of the technologies that can produce the necessary quality, while being open to technologies that are under development and might be suitable in the future. We describe a process for sampling that is based upon error estimates from past studies and includes methods for estimating sample size and recruitment strategy. Accuracy, validity and cost-effectiveness are all important considerations and we propose methods that take into account time per subject, size and skill of the data collection team, and the number and type of measurements and demographic variables needed to meet stakeholder requirements.
The research examined: 1) factors influencing the budget and resources, 2) international and Australian academic and 'grey' literature about national sizing surveys and international standards in other leading countries, and 3) processes to define the scope of the Australian Body Sizing Survey. It addressed the key features of stakeholder engagement and how this would determine the range and type of measurements to be obtained. It also described the systems engineering model that would be used to develop the testing required to finalise the survey method, business plan and costing. It outlined possible sizing survey methods including recommended sampling methods, recruitment strategies and data management.
The research findings can be grouped into six key areas that are critical to the effective and efficient development of the Australian Body Sizing Survey. Firstly, 1-D and 3-D data types provide different information and both are essential for a high quality, useful survey. Secondly, new 4-D (high quality 3-D scans captured while the subject is in motion) could provide a cost effective way to capture fit information. Thirdly, it is critical that stakeholders be engaged early in the process. Fourthly, although ISO Standards provide basic templates for the development of a survey, they are not sufficient. Fifthly, a systems-engineering approach balancing technical factors, cost, time, and needs, is required, and lastly, the value propositions from industry demonstrated that a survey conducted in the right way will enable better design and safer and healthier work places and equipment.

3D Scanning of Dutch Military - Secular Trends in PCA for 18,000 Soldiers #11

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The Netherlands Military Forces started 3D whole body scanning of their recruits in the year 2003. 1D-body dimensions are derived from the scans to supply the best fitting size without human involvement. In order to investigate secular trends in body dimensions, the dataset of 3D scans was cleaned and analyzed for inter-individual differences using principle component (PC) analysis. Changes in body dimensions and body posture were quantified over the period 2003-2012 and digital design extremes were constructed.
The original dataset of 18221 scans was cleaned to 15231 male and 2390 female scans (97%). A male and female model was constructed from 200 selected men and 200 selected women. Since the arm position was not standardized during scanning, it was necessary to separate the arms from the torso. The analysis showed that men and women differed most for stature (PC1), mass and inner leg length (PC2) and mass without inner leg length (PC3). These PC values hardly changed over the years. However, the PCs of the arms changed over the years due to changing preferences in posture.
The developed model enables quantification of the body shape and posture with only a small number of PCs. This means that the data can be stored and processed effectively. The generated design extremes may serve to optimize products related to the physical shape of soldiers.

From 3-D Scans to Design Tools #39

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Many products are designed for human use and need to fit the human body shape. However, current CAD tools are focused on the object to be designed and have little capability of accessing human shape information. 3-D anthropometry – an emerging field – leverages the recent advances in 3-D imaging technology, providing new opportunities for designers to access accurate, complete, and detailed human shape information. However, the 3-D scan data are drastically different from the traditional anthropometric data, which are linear 1-D measurements. New geometry processing and statistical techniques have to be developed in order to make the 3-D data usable. In this paper, we describe these tools and techniques and their potential use in augmenting or integrating 3-D anthropometric data with existing CAD tools. In particular, we discuss three types of tools: 1.

Data exploration tools – visualizing the space of human shape and helping understand shape variability; 2. Shape generation tools – bridging the traditional data and the 3-D data; and 3. Sizing tools – helping design sizing systems that optimally accommodate populations.

3D Anthropometric Data Set of the Head and Face of Children Aged 0.5-6 Years for Design Applications #43

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In product design, human body measurements are essential when it comes to products that need to fit the contour of the human body in order to be effective. When designing these products, designers must integrate anthropometric dimensions in their design process to optimize the usability and functioning of the product. In spite of the wide variety of available anthropometric tools, designers most commonly use traditional (1D) anthropometric information when designing and evaluating products. This does not always offer the detailed information of the human body shape required to develop a product with an optimal fit. This is especially the case for medical products such as respirators and orthesis, but also in consumer products, such as helmets and protective glasses.
3D anthropometry however, creates a significant opportunity for designers by offering detailed information regarding the shape of the human body. Advances in 3D imaging technologies have reinforced these possibilities in the field of anthropometry. With the use of these technologies, it is possible to capture a complete 3D image of the whole body in a matter of seconds, making the measurement process less invasive and therefor more suitable for populations that are difficult to measure with traditional means like children, elderly and physically impaired persons.
The objective of this study is to map the variation of children's heads and faces and to define a new way to present this 3D anthropometric data so that it is tailored for use in design. For the first stage of this study, an anthropometric survey was conducted, whereby the heads and faces of children between the ages of 0.5 to 7 years old were analysed. Around 300 boys and girls were measured combining traditional anthropometric measurements with measurements derived from 3D images. All subjects were photographed using a digital three-dimensional photogrammetry system (3dMD Face imaging system). This paper presents the preliminary 3D data set of the heads and faces of children aged 0.5-7 years for design applications and shows the summary statistics for some of the traditional anthropometric measurements.

Web Based 3D Visualization and Interaction for Whole Body Laser Scans #27

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A web based system that allows the user to select, sort, and measure 3D bodies using displays inside of ordinary web browsers without the use of 3D plug-ins is presented. Our system, AnthroWeb3DMeasure (AW3DM), allows the user to visually explore a set of 3D laser scanned bodies. The bodies we use come from the CAESAR data set, however nothing inherently limits applicability of these techniques to this specific data set. The user is presented with a set of controls, the 3D view of the body, and a tabular view of demographic data associated with each body. We use X3DOM as the basis for the 3D body visualizations. X3DOM is a "declarative 3D" language that enables us to place the graphical elements of the body directly into the DOM (Document Object Model) of the web page itself. This has significant implications for the extensibility and practical usefulness of the system as it is not dependent on arcane plugins and is interoperable among all modern web browsers.

From S-M-L-XL to Mass Customization. Case Study: External Ankle Sprain Protection with Exo-L #49

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This paper presents the conducted research and development when creating Exo-L: 'A bio inspired external ligament that effectively supports the ankle, without reducing the feeling of comfort and flexibility'. It uncovers some of the early research and the patented technical proof of principal, as well as a glimpse of the roadmap to Exo-L's market introduction. It will be discussed how a customized product proves to be superior compared to an universal set of products in certain situations, and how the current state of technology enables customization on a large scale.

An ankle sprain injury occurs when high impact forces make the foot rotate beyond its normal range of motion. In addition to adequate training, an external support helps to prevent these injuries from happening. The similarity between the evolved principles of the foot's ligaments (biomimicry) was guiding the analysis and concept development process of Exo-L and a solution was found that supports the relative motion between two rigid parts (the foot and the lower leg) by an external ligament means.
It was recognized that most previously available ankle braces rely on fixing some universally sized components tightly around the ankle region and therefor reducing the feeling of freedom, which is a key element for performance. Exo-L transfers forces from a special attachment feature on the shoe to the lower leg by introducing a perfectly fitting half open clip, allowing pressure to be exerted onto the malleoli. Exo-L is tailor made by 3D-scanning the user's ankle and subsequent 3D-printing of the product.

TECHNICAL SESSION 6: FULL BODY SCANNING SYSTEMS

New Traveling Type 3D Full Body Scanner #71

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In this paper, a newly developed 3D full body scanner is descried. The new traveling type scanner is the most compact 3D full body scanner ever of all time, and it consists of three towers. By developing a much smaller new 3D camera (projector and video camera), each tower became significantly lighter and thinner compared to that of our previous body scanner. Moreover, each tower can be disassembled into three separated modules each having one 3D camera. In addition, by providing a CPU in each tower, 3D data obtained at each tower is decentrally processed allowing the use of a laptop PC as a control computer, which realizes real portability of the scanner system. Moreover, an interpolation program of scanning data was developed so that the scanner can output 3D human body data without deficits.

Essential Elements of 3D Body Scanning for Applications in Retail and Research #02

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3D body scanning first emerged as a human body measurement tool in technical and research application areas in the 1990's. In recent years lower cost and more highly automated systems have been finding their way into retail applications. The body scanning protocols for technical applications have largely been driven by the anthropometric/ergonomics technical communities. Retail protocols have been driven by agents of the commercial retail businesses in the apparel, fitness, and medical communities. Though there is some overlap in these protocols, there are also significant differences.
Size Stream has developed a low cost automated 3D body scanning system with the intention of meeting the requirements and needs of the full spectrum of applications from technical research to retail applications.
In order to meet the needs of both technical research and retail body scanning applications many features are essential beyond simple 3D data capture. These include: (a) robust hardware and software, easy to install, operate, and maintain ; (b) simple user interface, fast and convenient data capture; (c) private and comfortable scan experience ; (d) automatic data processing to organized meshes and aesthetic avatars; (e) comprehensive automatic and manual measurement tools ; (f) compliance to recognized standards, accommodation of custom measures ; (g) color texture capture aligned to the 3D data; (h) 3D capture in real time, 4D body scanning .

Extreme Body Scanning - The Future of Very Accurate Body Reference Models - An Update on the Collaboration Between 3dMD and MPI for Intelligent Systems #74

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Born at the first conference in Lugano, 3dMD and MPI-IS (Prof Michael Black) have established a very close collaboration to push the boundaries of highly accurate positional body scanning. At the 3rd Conference, Chris Lane and Michael Black premiered the research into developing very accurate articulated body avatars using complex protocols for capturing over 100 body postures and how this is being used to create an increasing library of virtual mannequins across broad age and posture variations. This session will provide both an update on this project and the new scanning system which scans full body activity at 60Hz with sub-millimeter accuracy and markerless surface tracking. The research will enable reference models to be built which analyze skin and fabric flow in response to a wide range of physical activity.

VITUS 3D Body Scanner #06

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For more than 15 years VITRONIC has been a world leader in body scanning. VITRONIC develops and manufactures body scanning systems for different areas of applications and to suit different international market.

TECHNICAL SESSION 7: BODY SCANNING SYSTEMS & TECHNOLOGIES

Line-structure Laser Human Body 3D Scanner with High Resolution #40

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At present, digital human modeling (DHM) is a research hotspot due to it has wide applications. This paper develops a high resolution human body 3D scanner which conforms to triangulation principle and adopts line-structure light scanning mode. In accordance with modular design concept, the scanner can be divided into optical sensing and movement mechanism module, motion control and image capturing module, image processing and 3D reconstruction module. The scanner is composed of 4 pillars which create a square with the diagonal length 1644mm between optical sensors, and the pillar's height is 3050mm. the measurement volume is a cylinder with radius (in horizontal plane) R=500mm and height (vertical orientation) Hv=2000mm. there are 8 optical sensors totally in the scanner, and the typical resolution of each optical sensor is 0.7mm/pixel along x axis and 1.0mm/pixel along y axis. The scanning resolution can be changed from 2mm to 4mm, and the time used is from 20s to 10s correspondingly. The reprojection mean error displays calibration results is better than 0.35mm using a dynamic target designed with 2D electric translation stages and ceramic gauge block. The point cloud acquired from a real person shows that the scanner is high effective though some aspects should be improved later.

Spread-Sheet Execution of Shape-from-Shading for Human Back Surface Measurement #45

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Shape-from-shading is a shape measurement technique which features simple data collection. However, it is restricted in the types of objects it can measure. These characteristics do make it suitable for some types of body surface measurement, but it does not yet seem to have found many applications. This paper looks at whether the simple data collection can be augmented by equally straightforward data processing to make it feasible for scoliosis monitoring. Experiments have confirmed the basic concept of back surface measurement by SFS, but that further practical refinement is needed.

High Accuracy Passive Photogrammetry 3D Body Scanner #38

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This paper presents a new and high accuracy passive photogrammetry device intended for the three-dimensional scanning of the full human body. This device, named Bodygrammer, does not need laser beams, structured light, strips or any projection on the human body. It just takes a series of pictures of the body inside a cabin, whilst wearing an elastic mesh. Thus, it comprises only cheap and simple commercial elements to build, in just a few seconds, the digital 3D model of the body, also known as an avatar.

Since it is based on synchronized pictures, its acquisition time is only hundredths of second, avoiding unwanted movements by the person. This dramatically reduces the acquisition time while providing high accuracy in the results. For end users, the Bodygrammer is completely harmless. By using an elastic mesh there is no need to get naked in order to allow the system to take the images, which are deleted automatically right after the generation of the avatar. As the mesh mildly constrains the body, the resulting avatar is highly suitable for apparel applications.

This device performs very intensive calculations by means of a newly developed software based on GPU (Graphic Processing Unit) computation, that quickly obtains the avatar from just the pictures. The system allows us to get both manual and automatic 3D measurements such as chest circumference, limb length, waist

perimeter, etc.
The Bodygrammer has already been thoroughly tested with real people for anthropometric studies. The resulting measurements have been successfully validated using third-party 3D contact techniques. In addition, all the individuals measured with the device have reported a satisfactory user experience which is of vital importance in order to be widely accepted in the real world.

RECOVER3D: A Hybrid Multi-View System for 4D Reconstruction of Moving Actors #68

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4D multi-view reconstruction of moving actors has many applications in the entertainment industry and although studios providing such services become more accessible, efforts have to be done in order to improve the underlying technology and to produce high-quality 3D contents. The RECOVER3D project aim is to elaborate an integrated virtual video system for the broadcast and motion pictures markets. In particular, we present a hybrid acquisition system coupling mono and multiscopic video cameras where actor's performance is captured as 4D data set: a sequence of 3D volumes over time. The visual improvement of the software solutions being implemented relies on "silhouette-based" techniques and (multi-)stereovision, following several hybridization scenarios integrating GPU-based processing. Afterwards, we transform this sequence of independent 3D volumes in a unique dynamic mesh. Our approach is based on a motion estimation procedure. An adaptive signed volume distance function is used as the principal shape descriptor and an optical flow algorithm is adapted to the surface setting with a modification that minimizes the interference between unrelated surface regions.

TECHNICAL SESSION 8: ANTHROPOMETRIC STUDIES & SURVEYS

Difference in Shape and Dimensions between Adult and Children Feet Based on 40.000 3D Scans #47

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Human foot shape affects the fit of shoe significantly. Some shoes fit better to some types of feet, while other shoes fit better to other types of feet. The paper analyzes human feet from the perspective of shoe fit. We analyzed and compared the width and length of feet as well as the shape of toe area (by classifying feet into Greek, Roman and Egyptian type). We focused to differences between adult and children feet.
In the analysis we included a huge number (more than 40.000) of 3D scans of human feet. The 3D scans were obtained in EU project Dorothy, internal foot scanning campaigns and mostly from feet scanners installed round the world. Currently about 170 scanners are installed in retail shops and are available for feet scanning and for recommendation of shoes to end customers.

Comparison of European and Asian morphology #31

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Due to the increase in global brands the effect of geographic origin and racial background on morphology has become increasingly important when developing sizing systems. Previous research has identified that there are significant morphological differences between countries. It has been suggested that the variations of body dimensions of different groups can be observed in terms of overall body size and bodily proportions. Therefore, it is crucial for global brands to understand the differences in morphology across the different regions they trade in, and to determine if one sizing system is capable of providing good fit across all regions. This paper aims to determine the key differences between Asian and European populations with regards to key anthropometric measurements.
To determine the difference between the two populations, 6000 adult 3D scans were analysed (2200 Chinese, 3800 European (French and Spanish), with 32 body measurements extracted. The data was categorised into 4 groups: Chinese male, Chinese female, EU male and EU female. Initially, the two populations were analysed with regards to the mean, 5th and 95th percentiles, for each of the 32 measures, enabling both the average population and range to be analysed. Secondly, statistical analysis was performed to determine where the key differences between the populations was and if these differences were significant.

The data analysis identified key differences between the morphology of the two populations with regards to both the mean and variation within the population for men and women. Significant differences were found for 14 and 16 of the 32 measures for men and women respectively. Further analysis identified that as well as differences in size, demonstrated by the analysis of individual measures, there were also significant differences in shape. Shape differences were highlighted through the comparison of the ratio of different measures. One example of this was leg length, where the Chinese population were found to have significantly shorter legs, when their overall height was equal to that of their European counterpart.
The results from this study identified that there are several differences between the European and Chinese populations with regards to both shape and size. It was found that the difference between the female populations was larger than that for the men, with a significant difference being found for a greater number of measures. These findings suggest that it is of interest to develop individual sizing systems for each region (Europe and Asia) to accommodate these differences and to maximise user satisfaction.

SizeBR - The Brazilian Study on Anthropometric #26

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In order to standardize and guide the clothing manufacturers in developing products to meet the textile and apparel chain, hence the construction of the gradations and modeling clothing in relation to standards bodies, Senai CETIQT, in 2006, began, still incipient, the mapping of different configurations of bodies Brazilians. Over those seven years, as the methodology was outlined and matured, the study of Senai CETIQT passed through several stages. First acquired tools for manual measurement and conducted a feasibility study with a small sample group comprised of students and staff of the institution itself. As the results were satisfactory, a new phase began with the acquisition of a body scanner and specialized services standardization of uniforms of the armed forces and auxiliaries. With the implemented methodology, it was possible a major step toward the anthropometric characteristics of the standard body of Brazilian design SizeBR. In 2010 Senai CETIQT listed the main consumption centers spread across five main regions: South, Southeast, Cento West, North and Northeast to start the first scientific study conducted by anthropometric scanning technology at the national level in order to behold the great dimensions of Brazil. Seeking greater breadth of research, the team of Innovation Management, Studies and Research through the line and Consumption Behavior of Senai CETIQT developed a questionnaire about consumption habits of Brazilians to be applied in conjunction with measurements to be obtained in these regions. For each consumption center, depending on the served population, we applied the statistical theory of sampling to define the number of Brazilians to be measured (the international standard ISO 15535:2012). So a specialized team consisting of technicians in the design, engineering, anthropology, social sciences, electronics and ergonomics was trained to go into the field and perform automatic measurements manuals and treat the images obtained by body scanners. Currently the project team SizeBR dedicated to the completion of the measurements and the statistical treatment of the data and has the forecast finalization of the national stage for males and females between 18 and 65 years and consequently Senai CETIQT. Continuing expansion SizeBR seeking to meet the other segments, Senai CETIQT is acquiring two more body scanners, one for feet and hands and another for head, in this way to meet with that segment of the field of Fashion.

EUROFIT - Integration, Homogenisation and Extension of the Scope of Large 3D Anthropometric Data Pools for Product Development #07

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Over the last decades, human body metrics have been used to improve human-product interaction. Along this period, the use of 1D-measurements in “classic” ergonomic applications (e.g. workplace design) has been extended to consumer goods industries such as the automotive, apparel, furniture or orthopaedic products. New technologies for gathering, storage and analysis of anthropometric data (i.e. 3D scanners) have boosted the availability of digital anthropometric resources. Since 1999, more than 16 large-scale national 3D body scanning surveys have been conducted around the world (six in Europe). The availability of these data pools has created the opportunity to exploit shape information beyond todays 1D-measurement based use and methodologies.
However, these data pools are dispersed and heterogeneous (e.g. different scanning technologies, different protocols) and, above all, the exploitation of 3D data at industry level requires knowledge, skills and resources

beyond the means of companies, especially SMEs. These barriers have until now strongly limited the utilization of existing 3D shape data to scientific and academic research.
The paper introduces the EUROFIT project initiative (www.eurofit-project.eu). EUROFIT is a joint co-operation project partially funded by the European Community started in June 2012. EUROFIT vision is to unleash the huge potential provided by the increasing number of databases of 3D body scans for the European consumer goods' industries.
The project aims to implement an online platform and an open framework that enables designers and industrialists to draw useful 3D shape information and use it in their product development processes in an easy and direct way. R&D work focusses on the systematization and extension of methods for 3D shape data aggregation and analysis in a reliable but economically sustainable way, as well as on the development of sector-specific applications and user-friendly interfaces. The overall EUROFIT approach, the main technical and scientific challenges as well as first results will be presented.

Size China 3D Anthropometric Survey #78

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The Size China 3D anthropometric survey used a combination of traditional anthropometric methods and current laser scanning technologies to create a high resolution 3D digital database of the Chinese head shape. The survey followed international standards for the collection of statistically accurate 3D data on Chinese head shape. Scanning was done at seven different sites across mainland China, collecting data for use in the design of "Chinese fit" products for the head and face.

TECHNICAL SESSION 9: MEDICAL APPLICATIONS II

Automated Detection of Breast Contour in 3D Images of the Female Torso #44

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Stereophotogrammetry is finding increasing use in plastic surgery, both for breast reconstruction after oncological procedures and cosmetic augmentation/reduction. The ability to visualize and quantify morphological features of the breast facilitates pre-operative planning and post-operative outcome assessment. Breast contour is an important attribute for quantitative assessment of breast aesthetics. Based on the detected breast contour, relevant morphological measures such as breast size, shape, symmetry, volume and ptosis can be determined. In this study we present an approach for the automatic contour detection of the lower breast in three-dimensional (3D) images. Our approach employs surface curvature analysis. We first identify the points with the lowest Gaussian curvature within the one-ring neighborhood on the surface mesh, and then apply the random sample consensus (RANSAC) algorithm to non-deterministically estimate the lower breast contour from the set of low curvature points.

Towards a Case-Based Reasoning System for Predicting Aesthetic Outcomes of Breast Reconstruction #46

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As many breast cancer survivors are candidates for multiple types of breast reconstruction, they need help visualizing possible outcomes to make optimal decisions about breast reconstruction. The purpose of this study was to develop a prototype of a system that could help women visualize possible breast reconstruction surgery results by displaying examples of reconstruction outcomes achieved by patients with similar pre-operative features. We present a prototype case-based reasoning (CBR) system that queries a database of women who have already undergone breast reconstruction surgery to retrieve a subset of cases that were pre-operatively similar to the test patient. Similarity is assessed in terms of features such as breast volume, patient age, and body mass index (BMI). In our prototype CBR system, the prior cases are reused in a straightforward manner;

we simply present the post-operative 3D images of the cases that were pre-operatively similar to the test patient. The prototype CBR system was built on the data obtained from 47 patients. For each patient, we obtained 3D images before and six months after the initial breast reconstruction surgery. From these images, we quantified left and right pre-operative breast volumes. In order to retrieve cases that were pre-operatively similar to a given test patient, we applied the k-nearest neighbor algorithm (based on Euclidean distance) on the pre-operative features. We demonstrated the usefulness of our CBR system by presenting the sample query, which showed visually similar reconstructed breasts compared to the real reconstruction outcome.

Breast Augmentation Virtual Surgery using 3D Body Scanning - Bridging the Gap between Patient Expectations and Surgical Practicalities #51

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Background. Breast augmentation is an example of cosmetic surgery. The patient has a preconceived idea of what her ideal augmented bust size would like to be. Typically, the images in her mind are derived from magazines, television shows and perhaps friends who have had the surgical procedure. She generally thinks of bust cup sizes. The surgeon, on the other hand, thinks of bust volumes in terms of cc's and implant sizes. This dislocation between the surgeon and the patient often leads to dissatisfaction of surgical results, mainly due to lack of a common language. A technique in use today bridges patient expectations with surgical outcomes.
Method. A commercial 3D body scanning system has been deployed to scan the pre-operative patient. Common measurements are extracted and a printout is presented to the patient and surgeon for review. The patient selects what she believes would be her desired bust size. The surgeon selects three different implant sizes. The body scan model is then exported to a data modeling program. Three different models are produced using the selected implant sizes. These models are brought back into the scanner via software conversion, and measured as if the person underwent the surgical procedure. 3D whole body models are produced with volumetrically accurate bust sizes and presented to the patient and surgeon for final consultation.
Results. The accurately augmented models range from lower cc implant sizes to larger cc implant sizes. Corresponding measurements from the scanner software produced bust measurements that the patient could understand. The 3D whole body models allowed the patient to gain an understanding of overall proportion for each selected implant size. The patient selected the implant model she thought best met her wishes, felt engaged in the selection process and gained a greater degree of expectation of the surgical result.
Discussion. These predictive breast augmentation models have proven to be highly accurate, when compared with post-operative scanned measurements. The surgeons gained confidence in selecting the implant size best suited for the patient, and the patient to some degree of responsibility in selecting her "look". Implant "re-dos" reduced significantly once this program was adopted, and greater patient satisfaction was achieved.

TECHNICAL SESSION 10: BODY SCANNING FOR APPAREL II

Analysis of Lower Body Change in Active Body Positions of Varying Degrees #66

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Recently three-dimensional body scanners have been used to analyze changes in body measurements in active positions. The purpose of this study was to analyze the change in body surface measurements of knee and hip in active positions in greater detail, comparing a standing posture to postures when lifting the right leg to 5 different heights. Six female participants, average age 22.8, were scanned for this study. Starting from the knee point and hip point, 20 landmarks were placed on each participant at 5cm incrementswhile in the standing position. The distance between each adjacent point was compared and analyzed in scans of the 6 different postures. The angles and distances between knee central points and knee side points were also compared. As the leg angles increased, the distance between each adjacent point located on the side knee decreased, the distance on the central knee increased, and the distance on the central hip increased with different amounts of increase/decrease depending on the distance of the landmark from the joint center. The height and angle between the knee central point and knee side point increased with increasing leg angle. The results from this analysis provide a more precise indication of active leg positions in order to better design active pants.

3D Product Development Based on Kinematic Human Models #14

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3D product development is a very interesting topic for a widely range of applications on the garment industry. Although the 3D scanning of human bodies is widespread the pattern construction process is done mostly in 2D. One reason is the unusable standard scan posture. Our approach uses scripting to develop a kinematic system inside scan data in a widely automated process. The kinematic system consists of bones and muscles and deforms the surface of the scan data in a nearly realistic manner in any required posture. All modeling and animation work is done in Autodesk Maya.

Volumetric and Space Requirements of the Offshore Workforce: The Effects of Donning a Survival Suit #29

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Confined space working is common place within the offshore oil and gas infrastructure and it is a person's absolute size that governs his/her fit within this built environment. The design and adjustability of the environment must be based on the assumed size of the workforce, most commonly assumed to be the 95th percentile of the male size. The last anthropometric survey of the UK offshore workforce was conducted almost 30 years ago and since then the average weight of the workforce has increased by 19%, although the size and shape change associated with this increase remains unknown. With advances in portable 3D scanning technology and its potential for anthropometric measurement, this study aimed to quantify the volumetric and space requirements of the offshore workforce and size increases associated with donning personal protective equipment. Forty-three male participants were measured using both a static Hamamatsu and a portable Artec L 3D scanner in three different clothing assemblages. Volumetric and linear measures indicated a 71.3% increase in total body volume and a 101.9% gain in space requirements associated with donning a survival suit. Size increases due to survival clothing was found to have a close relationship with BMI; smaller individuals increase in body volume and space requirements comparatively more than their larger counterparts, r=0.815 and r=0.659 respectively. This pilot study identifies a need for further research into space requirements, especially in confined spaces and using specialist clothing.

Use of 3D Body Scanning Technique to Investigate an Effect of Garment Design on Heat and Mass Transfer in Clothing #50

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The heat and mass transfer in clothing do not only depend on the properties of fabric but also on the variation of the thickness of air layers and the magnitude of the contact area. The garment design and the body geometry have major influence on the above-mentioned parameters. Thus, this project addressed the effect of the fit of sport garments for female and male body shapes. Different garment designs were developed and confectioned considering anatomical and physiological gender differences. Each garment was subjected to 3D scanning and analysis of air gap thickness and contact area by imposing 3D scans of the nude and dressed manikin and advanced post-processing in dedicated software. It was found that the distribution of contact area and thickness of air layers is similar for both male and female upper body except for the breast and lumbar area. The knowledge gained from this study could be used to improve and individualize functional garments and to help in design process of body-mapped garments.

A Novel Approach for Fit Analysis of Protective Clothing Using Three-Dimensional Body Scanning #13

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The purpose of this study is to explore a proposed approach to quantitatively characterize a three- dimensional (3-D) fit. A 3-D body scanning technique was applied to capture the contour of nude and clothed manikin. The mesh model formed from nude and clothed scan by Rapidform software was aligned, superimposed and sectioned. From the neck to cuff, total 72 horizontal sections with equal interval of 2 cm were developed. The air

gap size and distribution of overall and local body surface were analyzed. The total air volume was also calculated. Fit analysis was conducted on several protective clothing. The effect of fabric properties on air gap distribution was explored. The results indicated that average air gap of the fit clothing is around 25~30 mm and the overall air gap distribution is similar. The air gap showed uneven distribution over the body and it related to the body geometry and fabric properties. Larger size of air gap in legs and abdomen was observed. The air gap in chest, pelvis and arms, however, is minimal. The air gap over convex area is smaller than that of concave area. Coverall made of stiff fabric provided large air gap size. The research finding provides a technical base for clothing engineer to understand the overall fit associated with protection, thermal and movement comfort.

TECHNICAL SESSION 11: MORPHOLOGY ANALYSIS & MEASUREMENT

Analysis of Morphological Variation of the Knee for Brace Development #54

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Introduction . Over the past 20 years there has been a significant increase in the participation in recreational and organised sport. Associated with this is the desire to continue training through minor injuries as well as maximise performance with the help of external aids such as knee supports, reducing strain and increasing proprioception. Associated to these types of products are advertised user benefits. However, for these benefits to be upheld it is important that the support applies the correct amount of compression in the appropriate area. Therefore, this study aims to evaluate European knee joint morphology, create separate size divisions and evaluate the morphological variation of the knee within each size through the use of 3D models.
Method . 1800 scans of European legs (French, Spanish, Portuguese, Germany) were captured using an Artec white light scanner. Principal component analysis was used to identify which of the standard measures used within knee support development should be used to categorise the population. The scans were then analysed through cluster analysis to identify how many sizes were required and how to separate the sizes to obtain 80%+ coverage of the population. Finally, all scans within each size category were used to calculate an average leg, with the centred circumferential standard deviation per 1 mm to be mapped to create a 3D model of the average leg, average +2SD and average -2SD.
Results . The PCA results identified that circumferential measure can be used to explain 93% of the variation within the population, with the measure 8cm above knee joint centre having the highest correlation with this factor (0.98). The cluster analysis identified 3 size categories within the data providing 81% coverage of the European population. An average leg was created for each size, with the standard deviation of each centred circumference calculated. To maximise coverage 2 standard deviations were used to calculate the variation in leg morphology and the location of greatest variation. As the size category was calculated on the +8cm measure the variation in upper leg measures (+8 and +12cm) was significantly lower than the knee and lower leg (-8cm) measures, 13%, 10%, 14% and 15% respectively.
Conclusion . The results identify that there is significantly greater variation in calf circumference compared to other anatomical references for knee products. The results identify that through the development of a new sizing system over 80% coverage could be achieved whilst minimising material elongation to less than 15% to ensure this is obtained.

Complete Spacial Evaluation of the Preoperative Bariatric Patient - New Insights into Body Composition #53

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Background. Current techniques to evaluate the physical characteristics of the pre-operative bariatric subject are generally limited to height, weight and perhaps anthropometric measurements such as waist and hips. By keeping the height and weight values, and using a commercial 3D whole body scanner and associated measurement software, one can provide a complete spacial evaluation of the subject, including excess volume, excess fat and fat density.
Methods. A commercial 3D whole body scanner routinely used to document physical measurements of bariatric subjects was programmed to yield volume and surface area measurements. Weight and height were recorded. Excess weight was determined using traditional table look-up. Bulk volume of the patient was provided by the scanner software. Excess volume was then calculated. Excess weight was divided by excess volume to

determine excess fat density, and an excess fat scale was then derived. Tables were created to evaluate volume, surface area, excess volume, and fat density. These new insights, combined with measurements provided by the scanner along with BMI were compiled and comparisons were made between various subjects.
Results. By determining excess volume and fat density, and comparing it to traditional obesity indicators such as BMI and waist/hip ratio, a better understanding emerged about the physical shape and often the physical condition of the morbidly obese subject.
Conclusion. The introduction of volume, combined with weight and height has opened up a new dimension into how we characterize and evaluate the morbidly obese condition. These values, along with measurements and other common indicators yield a complete physical characterization.

3D Facial Analysis Software for Before and After Comparison #72

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Spacevision developed a software which can align two 3D faces automatically by a machine learning technique. With automatically aligned two face data, the software provides 3D comparison techniques between before/after faces, such as heat-map visualization, cross-section and the other geometric measurements. We believe the software will open up a new application for 3D face scanners in especially beauty salons and aesthetic shops.

Reproducibility of Body Volume Assessments in Survival Clothing in Fixed and Portable Scanning Systems #30

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The recent development of portable 3D scanning systems for industries such as animation and museum artefact digitisation have considerable potential for applications involving human body measurement. However, this requires a system for validation of measurements against a criterion, which this study aimed to provide. Forty four adult males were scanned in duplicate in both a fixed Hamamatsu and portable Artec L scanning systems in two postures and two different clothing assemblages. Following inspection of all scans, complete data for duplicate scans of 38 participants were available for the study. Both scanners demonstrated good precision, however significant differences in body volume prevailed for both egress and scanner postures in form-fitting clothing and the scanner posture in survival suit scans, with the Hamamatsu providing greater volumes than the Artec system (by 2.7, 2.8 and 2.1 litres respectively). Regression analysis indicated the results from the portable scanner explained between 96 and 98% of the variability in the results from the fixed scanner. The biases in body volume probably relate to different software approaches to its calculation, and a possible interaction with posture and clothing. Validation of the Artec against the Hamamatsu system provides valuable information for its use in field and industrial settings.

Advances in Anthropometric Accounting for Ear Digital Modeling #60

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Anthropometry for general digital human modeling (DHM) may be enhanced and improved in clarity, accuracy of text and illustrations by adopting analogies of standard concepts for business accounting terminology and data. Analogs and differences between the two systems are described with examples. These procedures can aid organizing, publishing and applying data on anthropometric dimensions, especially for the complex shapes of human ears. Implications of these apparently simple practices have led to far-reaching benefits regarding text and illustrations in documentation. They can benefit anthropometric surveys, reports, data documents and software for computer aided design (CAD) using digital human models. Also, many additional advances beyond double entry book keeping concepts have been suggested by applying basic engineering graphics practices to deal with the unusual challenges of wide variability in shape and size of human ears. These include (a) extensive new titles and abbreviations for previously numbered points, (b) new titles, abbreviations and descriptions for some newly invented points that needed correction and formal recognition, (c) new concepts for formally recognizing reference lines, planes and curved surfaces as end conditions (herein called delimitations) together with their titles and abbreviations, (d) inclusion of callouts for points, lines, and surfaces in two orthogonal illustrations for dimensions and for delimitations and (e)) new classifications and codes for path constraints for dimensions. The latter provide compact notation to distinguish between straight line and curved dimension,

especially if they have the same origins and terminations. Also included are new concepts for reference view planes for ears. These include an Ear Primary View Plane (parallel to ear width and length) and a set of closely related, cross-section planes that are perpendicular to it. The latter aid depiction of true lengths of dimensions relative to ear figures that are commonly published and avoid certain difficulties of attempts to use standard anthropometric principal planes and axes for describing and illustrating measurements. Such advanced accounting procedures offer further benefits for creating multi-population databases, accurately retrieving data from databases and applying data to CAD analyses and digital modeling. The revelations of this document can fill a need to improve all ear anthropometric survey dimension selections, definitions, illustrations in many related fields to facilitate digital modeling, and many articles about plastic surgery, forensics, health and nutrition, and design requirements for ear- related devices, such as ear buds, earphones, ear muffs and other protective gear.

TECHNICAL SESSION 12: BODY SCANNING FOR APPAREL III

Exploring Consumer Perceptions Toward the Use of Me-Ality Body Scanner for Clothing Selection in U.S. Shopping Malls #12

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The purpose of this exploratory study was to gain knowledge about consumer perceptions toward the use of 3D body scanning technology for their clothing selection. The specific objectives were: 1) to explore U.S. consumer's clothing fit and sizing issues, 2) to understand the level of consumer satisfaction about his/her current clothing fit; 3) to explore the consumer perceptions for the use of the Me-Ality body scanner; and 4) to examine the consumer's level of motivation to use this technology in the future. A convenience sample of 18 consumers was recruited from two of the purposefully chosen U.S. Midwestern shopping malls that equipped Me-Ality scanners providing sizing recommendations to consumers based on their body scan. After the completion of their Me-Ality body scan experience, potential study participants were asked to complete survey questionnaires to understand their usage of this technology to find better-fitted clothing during their shopping experiences. Participant's ages ranged from 18 to 28. The sample consisted of 39% of males and 61% of females, and 72.2% of White European Americans and 27.8% of African American. The majority resided in the Midwest (94.4%) and had attended at least some college (77.8%). Both quantitative and qualitative data analyses were used for this study. The results of this study indicate that most participants were satisfied with their current clothing fit while recognizing apparel sizing was different among brands. Waist, pant length, and the bust for females were common areas of fit dissatisfaction, with participants often commenting that proper fitting jeans and pants were the clothing that were most difficult to find. Although participants were mostly neutral about the perceived usefulness of body scanning, almost all believed the scanning process and body scanner were easy to use. The frequent reasons for participants to use the scanner were to check their right clothing size, for fun, and because another person asked them to try the body scanning. Participants had an overall positive opinion of 3D body scanning and expressed their interest to use this technology in the future, especially obtaining their accurate sizing information in a retail store setting. During the data collection, researchers observed that the employees operating the Me-Ality scanners had to try to convince people walking by to stop and do a scan. One worker commented the most challenging part was getting people to stop and do it saying, "Most people don't know what the body scanner is, so they don't want to try it." Many of the Me-Ality customers were children and teenagers who were at the malls for leisure purposes and had the time to devote to the scanning process. Since young people have been found to be more technologically oriented, further research should be done in this age group. Further research is also recommended on other Me-Ality consumers in other geographic locations to provide a more representative population. With more consumer awareness and accessible locations, 3D body scanning technology could become more prevalent in the everyday consumer shopping experience.

Scan-to-Pattern Clothing Systems: A Systematic Approach #22

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Sizing systems for commercial off-the-rack clothing have historically been based on a mix of tradition, trade secrets and anthropometric data. More recently, large quantities of information from 3D body scanners have become available, creating a new source of data from which off-the-rack clothing can be sized and designed. [We note that some scanning systems are used for made-to-measure or custom garments, and those processes

are not the subject of this paper.] With these new, large, datasets available it is worthwhile to review the whole process of how to go from a scanner-produced anthropometric dataset to finished patterns.
The scanner itself should be validated for this particular application. Research has shown that scanners vary in the quality of the scan image, and the amount of missing data (as well as the software tools to estimate the missing data). Systems also vary considerably in the algorithms they use to extract the anthropometric dimensions. Leaving aside whether the extracted dimensions are “right” or “wrong”, it is important to know whether they are providing the dimensions that the user expects. Ideally, this validation should be done by an independent agency, but at minimum should not be done by the system manufacturer.
The resulting dataset should be edited to identify unusual values. Even the best scanning systems will occasionally produce peculiar values, typically because the individual being scanned violates some assumption made by the data extraction algorithm. There are a variety of techniques for data editing, including outlier checks, and comparisons of predicted with extracted values.
The dataset should be statistically weighted to the population of interest. Most datasets represent a sample of a particular population but are far smaller in number than the population itself. Since scanner samples are rarely completely representative of the target population, the database should be weighted to reduce the effect of the sampling discrepancy. Several methods for weighting will be discussed and illustrated.
The creation of the sizing system itself is the next step. This should be based on the type of garment being designed, but should also be based on the total variability in the population and the business decision about how much of the population to cover. In some cases a traditional grade can be used, but in some cases more atypical grades will provide greater coverage with fewer sizes. If the database is large enough, it is possible to use the individuals in each size as a mini-sample, and to identify the body dimensions for the individuals in each size. For smaller sample sizes, regressions or other linear approaches are preferred.
Using the central size in the system as the base size, the pattern or block itself is the next task. Here, the designer’s usual creative approach can be used. Finally, the patterns should be validated, again in the usual way, with fitting trials. Ideally, sizes from multiple points in the nested grade would also be validated in addition to the base size.
This systematic approach will allow a traceable path from scan data to verified patterns. Because it is systematic, it is amenable to changes in the process for specific garments, specific design populations or other unusual circumstances. It also allows designers update the sizing system as the population changes over time.

Analysis of Three Dimensional Torso Shape and Bodice Pattern of Elderly Japanese Women #37
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The population of individuals over 65 years old is growing rapidly. To provide well-fitting clothes for this population, it is important to clarify the difference in body shape between elderly and young women, and the quantitative relationships between flat patterns and body shapes. In this study, our aim was to clarify the factors that explain the diversity among young and elderly Japanese women’s body shapes. The subjects were 107 elderly and 230 young healthy Japanese women. Six VIVID 910 non-contact 3D digitizers were used to measure their torsos. In each subject, from the 3-dimensional torso surface, two-dimensional diagrams of the body surface were made using the 3D CAD software and would be the basic pattern for making clothes for that subject. To enable statistical analysis, the 3D data of each individual were transformed to a homologous model and analyzed. The average shapes of the two age groups were calculated and an age difference was observed. Upon principal component analysis of the homologous models, nine factors were extracted. Most of these factors could be effective input variables for pattern making in addition to ordinary size variables. The shapes of the body surfaces were observed in association with the principal component scores of the models.

Findings of a Breast Assessment Service and Implications for Clothing #59
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Since 2003, Body Aspect has collected 3D data on over 2000 female subjects as part of a breast assessment service for the UK’s National Health Service (NHS). The data includes women who have sought treatment for breast reduction, asymmetry correction and augmentation. Our service is aimed at helping the NHS to decide who should be considered for those treatments. But the criteria for acceptance are stringent. For example, 70% of the women referred for consideration for breast reduction are not eligible to receive an operation. For these women, finding suitable clothing, especially a bra or swimsuit, can be more of a problem than for the majority of

women. This paper presents some statistics on the data collected, discusses the issues relevant to these women and attempts to highlight potential opportunities for clothing manufacturers addressing this niche area.

Designing for Pregnant Women #76

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"It's positive!" Few words such as these have the power to change a woman's life forever. One may think her life will actually change nine months from them, but even during these nine months of pregnancy her whole body will go through a transformation. According to medical literature, women go through three trimesters, phases during which her body will change to accommodate the baby-to-be. Because women have had pregnancies for the whole span of human history, one would think the apparel industry would have acknowledged this and would have always been designing for them.

Our research shows that this is not the case, though, and so much could be done. When reviewing the literature, we learned that in the past pregnant women would wear their usual clothes until they no longer fit. From there they would wear oversize garments until they gave birth. Indeed, very little has been done in regards to pregnant women and the apparel industry and most of it has been done only in the last few decades. Moreover, it seems that many people think that the changes are only in her torso.

After we surveyed a group of pregnant women and young mothers, our results showed that contrary to what we read in the literature, they perceive their metabolic changes from the very first trimester. In addition, changes appeared not only on their upper part of their body but from head to toe. Moreover, surprisingly, this sample we surveyed seems to be "satisfied" with the clothing currently offered, just as people tend to be in a push marketing system. If designers and marketers are looking to focus on one specific target market, one where there is room for improvement when it comes to size, fit, and styles, maternity wear is definitely the one where it is time to shift form a push marketing strategy and move on to a pull marketing strategy with a consumer-driven concept. Pregnant women represent an undeserved market from this perspective. Thus, if manufacturers and retailers recognize the benefit of focusing on specific target markets and the importance of working with accurate body measurements in variety of styles related to a target market, pregnant women offer an appealing and dynamic target market. Imagine designing appealing garments that could be suitable for all three trimesters! It would be a breakthrough, innovative and sustainable way of designing and satisfying mothers-to-be.

TECHNICAL SESSION 13: KINECT BASED SCANNING

Accurate 3D Face and Body Modeling from a Single Fixed Kinect #15

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In this paper, we address the problem of both face and body modeling using a single fixed low-cost 3D camera (e.g. Kinect). Unlike other scanning technologies which either set up multiple sensors around a static subject or scan the static subject with a hand-held moving 3D camera, our method allows the subject to move in front of a single fixed 3D sensor. This opens the door to a wide range of applications where scanning is conveniently performed at home alone. While partial range scans of face are aligned rigidly, the body modeling is performed through articulated registration. At the surface reconstruction stage, we utilize the cylindrical representation for smoothing, hole filling and blending. Experimental results demonstrate the effectiveness of our modeling technique.

A Portable, Low-Cost 3D Body Scanning System #48

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Current 3D body scanning setups often requires extensive amount of hardware which needs to be accurately calibrated. Calibrating such systems can be a time consuming and error-prone task. Nevertheless, a well calibrated system generates accurate and fast 3D body scanning results. As a drawback, these setups are often statically built and therefore it is difficult to use them at different locations. New sensor technologies which have been established during the last years offer new possibilities for 3D body scanning tasks. This paper presents a portable, intuitively usable, scale-able and real-time capable 3D body scanner, which is affordable for everyone. Portable, since the system only requires a PC, one or more 3D depth sensors (e.g. PrimeSense Carmine 1.09).

Usable, since the system sensor is hand guided by a user. Scale-able, since any 3D depth sensor with different ranges can be integrated with the system and the scan area can be adapted to the sensor. Real-time, because every new frame from the camera changes the global model in real-time and gives the user feedback of the current status of the global model. To scan a person, the user takes the camera in his hand, starts capturing depth data from all required views by walking around the person to be scanned. As a result a polygon model can be exported and post processed. Due to the flexibility of the system, multiple sensors can be used at the same time. This enables the data of all sensors to be unified in the global model without the need of a complex calibration routine from the auto calibration algorithms of the system.

Distortion Correction of Depth Data from Consumer Depth Cameras #34

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Since the introduction of the Microsoft Kinect in November 2010, low cost consumer depth cameras have rapidly increased in popularity. Their integral technology provides a means of low cost 3D scanning, extending its accessibility to a far wider audience. Previous work has shown the 3D data from consumer depth cameras to exhibit fundamental measurement errors: likely due to their low cost and original intended application. A number of techniques to correct the errors are presented in the literature, but are typically device specific, or rely on specific open source drivers. Presented here is a simple method of calibrating consumer depth cameras, relying only on 3D scans of a plane filling the field of view: thereby compatible with any device capable of providing 3D point cloud data. Validation of the technique using a Microsoft Kinect sensor has shown non planarity errors to reduce to around ± 3mm: nearing the device's resolution. Further validation based on circumference measures of a cylindrical object has shown a variable error of up to 45mm to reduce to a systematic overestimation of 10mm, based on a 113mm diameter cylinder. Further work is required to test the proposed method on objects of greater complexity and over greater distances. However, this initial work suggests great potential for a simple method of reducing the error apparent in the 3D data from consumer depth cameras: possibly increasing their suitability for a number of applications.

Portable and Affordable Body Scanning in Made-to-Measure Apparel Using 3D Depth Sensors #77

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With the high cost of customer acquisition, MTM retailers often look to body scanning to reduce costs and decrease lead-times. Over the course of the last two decades, a vast array of body scanning technologies have been developed and have reached market. Though precise and highly engineered, these technologies often have faced hurdles in pricing, portability, and integration. Styku has generated significant learnings in its effort to address these challenges with innovative 3D depth sensors, portable tablets, and customer development in the made to measure market. Styku's MeasureMe software is a tablet-based 3D depth sensor that captures a person's full body scan, sync's with a private web server, extracts measurements, builds a 3D model, and integrates with existing CAD software for apparel design.

TECHNICAL SESSION 14: WORLD ENGINEERING ANTHROPOMETRY RESOURCE II

Anthropometric Dynamics of Pregnant Women and Their Implications on Apparel Sizing #20

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Anthropometric changes of pregnant women possess interesting dynamics that are mostly non-linear. These changes can be studied effectively with the use of 3-dimensional digital representations of their body at different time periods following gestation. This research discusses (a) a systematic evaluation of the non-linear changes observed in three key measurements of pregnant women – the bust, the waist, and the hip circumferences, and (b) comparison of these changes in terms of their compliance with the maternity wear sizing standard ASTM, D7197-13. Three-dimensional scanned data of 20 subjects from the study by Perkins et al [1] that include scans at six time periods along the span of gestation to post- delivery were imported into Polyworks for measurement. For each subject the levels for the bust, waist, and hip circumferential measurements were determined first for the scan at 4-16 weeks of gestation; measurements at all other time periods were taken at the same respective levels from the floor. Differential changes in the measurements between the periods of time windows are non-

linear within a given measurement and also between the measurements. Subsequently, these changes were compared with the estimated changes recommended by the ASTM standards, i.e., an incremental increase of 9 inches at the waist, 4 inches at the hip and 3 inches at the bust during the 7th month after gestation. Wilcoxon signed-rank test ($\alpha = 0.05$) results showed that the actual measurement changes are significantly different from the ASTM's estimated changes in the cases of the waist ($p = 0.025$) and the hip ($p = 0.0001$), while the bust measurement is in agreement with the ASTM's estimate. If the observed differences between the actual and the estimated measurements are taken into consideration, a more reliable and robust sizing chart would result.

Development of the Sizing System for Clothing Based on Korean Anthropometry Data #17

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Standardization is one of the most important invention that humans devised reflecting their culture and their history. For our purpose, standardization can be defined as an agreement among parties concerning the features/characteristics of clothes that one can consider as convenient, efficient and/or safe. However, more generally, all that each society of humans agrees upon, thus, language, writing symbols, rules or laws, which allows to maintain order in groups, customs to keep traditions and so on can be considered as the results or acts of standardization. A standard sizing system for clothes is a system that is developed based on body shape and size classifications method. To develop an efficient sizing system, we have to classify the database from the majority of the samples. This paper deals with secular trends of height, chest/bust girth, waist girth and hip girth spanning 1979 to 2010 as well as the morphological feature patterns for Koreans. It also investigates the comparison of the growth pattern and body proportions between male and female based on the anthropometric data samples of KATS taken from the 2010 surveys. The results are classified with body size and shape categories according to the drop values by age and sex in order to develop the new guidelines for the size designation systems based on these body dimensions from the analyzed anthropometric database. These new guidelines for the size designation system will eliminate the confusion that currently exists among countries and individual apparel designers.

Exploitation of 3D Body Databases for the Apparel Industry #41

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Nowadays each clothing company defines its own sizing chart to label the garment. The lack of regulations and the different labelling methods used on each country contribute to have a confusing buying process for the end users in terms of garment size selection. Depending on the brand, the customer selection can vary several sizes. This makes that customers need to try on many sizes to select the suitable one during the buying process. This is one of the main barriers to the growth of the online sales in the fashion market. The high number of returns and their associated costs (e.g. management, logistics and operations) represent an important economic burden for fashion companies.

A large number of technological solutions have emerged in the past years to help buyers in size selection, including commercial technologies to capture body dimensions, to predict the best-fitted size and to provide a fitting visualization. Nevertheless, these technologies have not achieved a compromise between cost, efficacy and accuracy enabling an extensive market penetration. Garment size selection from the anthropometry of the user body could be an interesting approach for e-Commerce. However, the current approaches have not been revealed as the definitive solution. A sizing system based on anthropometry requires the integration of technology and knowledge; namely, the acquisition and processing of the user anthropometry and garment fitting prediction.

There are many alternatives to register the anthropometry of the user: from accurate and expensive 3D body scanners to solutions based on Electronic Consumer Goods (e.g. Microsoft kinect, webcams). Accuracy, accessibility and usability are important requirements of a body measuring system that enables the size selection. The use of 3D body databases to guide the reconstruction of 3D body shape could be an interesting approach to progress in this way. The analysis of large 3D body pools using advanced 3D body shape modelling has also experienced a breakthrough. Research work conducted in the reconstruction of 3D body shapes from body measurements or from only two or three 2D contours using 3D body databases opens the door to the feasibility of having low cost scanners with an acceptable accuracy for size selection. By contrast, the fitting prediction, understood as the relationship between the body anthropometry and the garment dimensions, has

not been studied in depth. The fitting of the garment and the selection of the proper garment size depend on many factors (e.g. style, anthropometry, textile, personal preferences), hence, the use of size charts is not enough to obtain successful results.
The aim of the this paper is to present a proposal of new methods for the development size selection systems based on a 3D body acquisition process using 3D body reconstruction and a multi-fitting approach to predict garment size.

Designing Footwear for Uniformed South African Females - A Practical Study #58

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The main challenge inherent in designing for uniformed members remains the accommodation of large variances in anthropometry. Due to the rigid sizing rules characteristic to the footwear industry, designing to accommodate large foot shape variances requires out-of-the-box thinking. The aim of this study was to design female court shoes for uniformed members of the immensely diverse South African (SA) female population. Three dimensional (3D) foot anthropometry was collected for SA females by use of an InFoot laser foot scanner. The foot shapes characteristic to the SA female population were analysed by means of two techniques : 1) principal component analysis (PCA) of 13 foot measurements extracted from the 3D foot data, and 2) PCA of all 3D points on foot scans converted to homologeous 3D foot models (Di+). The most prominent foot shape variances observed (irrespective of foot length) included foot width and height, heel to ball of foot width ratio and arch height. In addition, the 3D shape analysis (homologeous foot models) highlighted toe box shape, heel shape and heel bone angle variances. The process of designing and developing female court shoes that will incorporate these foot shape variances included several iterations of last design changes and objective fit evaluations. The original last design was conducted by use of Computer Aided Design (CAD) last design software (ShoemasterQS Custom software) incorporating Cases of 3D foot forms identified to represent the ranges of variances in SA female foot forms. Objective and subjective fit evaluations were conducted on the base size (most popular size). Modifications were made to the last dimensions and shoe construction based on findings of the fit evaluations. A larger scale fit evaluation was conducted incorporating a full size range of the modified court shoe, together with the addition of another court shoe integrating style characteristics more appealing to the user population. The outcome of this fit evaluation highlighted that, although the court shoe provided acceptable accommodation for a large percentage of the SA females, certain foot form variances were not accommodated sufficiently. Currently, the largest design challenge remains with the accommodation of females with flat feet (very low arch heights), broad heels and inverted heel bones. The prevalence of females with very low arch heights was roughly 50 % of the females included in the large scale objective and subjective fit evaluation.

Functional Postures Assumed by Elderly People on Daily Activities - A Pilot Study for Interior Home Design #42

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The main purpose of this study was to scan elderly people in home activities postures selected according to frequency, difficulty in maintaining and safety, in order to create a functional postures database to be applied on interior home design. In the last 10 years the elderly proportion in the Brazilian population has had a marked growth. The percentage of people over 60 years increased from 8.6% in 2000 to 10.8% in 2010. In this context, falls are one of the most serious consequences of aging recognized as an important public health problem due to incidence, to health complications and to high assistance cost. Physical dependency and psychological troubles are common consequences for elderly people after home accidents due to loss of independence and loss of self esteem. The functional postures database will be used to study interior home lay-outs in order to improve safety and avoid hazardous workload postures at home. In the first phase of the study 10 women and 01 man were interviewed and scanned simulating daily activities postures. On a second phase elderly people movements´ will be captured through motion capture technology in home environments. Partial result analysis indicated the adoption of common postures, for example: on getting something from the floor, a forward trunk bending posture was mostly performed, instead of a knee flexion posture. The importance of this study is in understanding how to implement new interior lay-out design guidelines and to aid prevention programs in nursing-home institutions aiming to improve the elderly population´s quality of life and safety. This pilot study is part of two research studies supported by FAPERJ – Rio de Janeiro Research Support Agency.

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