Book of Abstracts

3DBODY.TECH 2017

8th International Conference and Exhibition on

3D Body Scanning and Processing Technologies

Montreal QC, Canada, 11-12 Oct. 2017

www.3dbody.tech/2017

Editor and Organizer

Hometrica Consulting - Dr. Nicola D'Apuzzo
Switzerland
www.hometrica.ch

TABLE OF CONTENTS *page*

TECHNICAL SESSION 9: MEDICAL APPLICATIONS II *page*

TECHNICAL SESSION 11: BODY SCANNING WITH CLOTHES ON

TECHNICAL SESSION 12: 3D TECHNOLOGIES FOR APPAREL II

TECHNICAL SESSION 13: SCANNING METHODS & TECHNOLOGIES

TECHNICAL SESSION 14: 3D BODY PROCESSING

INTRODUCTION

Introduction

Nicola D'APUZZO
Hometrica Consulting, Ascona, Switzerland

3DBODY.TECH 2017 - The 8th International Conference and Exhibition on 3D Body Scanning and Processing Technologies was held on October 11 th to 12 th 2017, in Montréal, Québec, Canada.
This event was organized by Hometrica Consulting - Dr. Nicola D'Apuzzo, Switzerland.
This conference and its parallel exhibition aim to fulfill the demand for an international event focused on 3D human body scanning, measurement and processing technologies, methods and applications. This event is the world leading technical platform dedicated to these specific fields.
In the last two decades, 3D scanning and processing technologies developed in other industrial sectors were successfully applied to the measurement and scanning of the human body. Methods and techniques are continuously ameliorated, more efficient and performing scanning systems are produced every year and new software tools are developed unceasingly.
The 3DBODY.TECH Conference & Expo serves as a platform for the information on the latest developments and interesting applications in various sectors, as well as, for building relationships and exchanging ideas between manufacturers, users, developers and researchers from around the world.
This book of abstract is divided in sections according to the conference's technical program and it includes the abstracts of the presentations and/or of the papers published in the proceedings of the conference.
Note: not all the presentations at the conference have a correspondent abstract and/or paper.

TECHNICAL SESSION 1: FULL BODY SCANNING IN MEDICINE & HEALTH

The Usefulness of a 3D Whole-Body Scanner for Uncommon Cosmetic Surgery Procedures

David B. STEFAN1, David A. GILBERT2
1 Novaptus Systems, Inc. Chesapeake VA, USA;
2 The Hague Plastic and Cosmetic Surgery Center, Norfolk VA, USA

Background: A 3D whole-body scanner appears to be best suited for measuring and documenting cosmetic surgical procedures that result in significant changes to the body. These procedures include breast augmentation, breast reduction and abdominoplasty. It is less useful for measuring changes resulting from procedures such as lipoplasty, which do not immediately result in pronounced changes of body contours. This paper presents examples of 3D whole-body scanning for less common cosmetic surgery procedures, and explores the usefulness of the 3D scanner as an aid for evaluating the pre-operative condition and as a tool for measuring and documenting post-operative changes of these surgeries.
Methods: A 3D whole-body scanner has been deployed for use in a cosmetic surgery practice in Norfolk, Virginia since 2002. Over the course of time, pre-operative and post-operative body scans from a wide range of cosmetic procedures have been collected. The 3D body scanner has shown its utility in capturing accurate whole-body models of subjects that underwent various surgical procedures. The scanner's measurement capabilities appear to be more effective for certain procedures and less useful for others. Case 1 examines circumferential pannulectomy. Case 2 examines a gluteal implant procedure. Case 3 examines a brachioplasty procedure. Case 4 examines chest contouring procedures.
Discussion: A general purpose, 3D whole-body scanner has certain limitations. It lacks definition for some regions of the body. This type of scanner is of little use for facial, hand or foot procedures, as these are outside the scanner's coverage area. In the case of a pannulectomy or gluteal implants, changes to the body are significant and the measurements are meaningful. The scanner provides less utility for procedures involving release of recessed body parts or removal of small growths. In these cases, pre-operative and post-operative measurements show little difference. The fixed position of the subject in the scan chamber limits the coverage for procedures related to the arms and neck. The 3D body scanner excels in coverage of the male chest region and is useful in chest contouring and gynecomastia procedures. The body scanner also has excellent coverage of the back side of the patient, including the buttocks region.
Summary: A 3D whole-body scanner has its place as a tool to document the pre-operative subject's body and measure overall dimensions. This has its own benefit as part of a 3D digital archive. In certain procedures, these body models and measurements can assist the surgeon in evaluating the subject's pre-operative body contours

and act as an aid for planning the pending surgery. Post-operative measurements faithfully document the results of these surgeries. The 3D whole-body scanner is not as effective in measuring procedures that result in less pronounced changes to the body, such as lipoplasty, removal of small growths, or procedures that are beyond the coverage area of the scanner. A table at the end of this paper enumerates the type of cosmetic surgeries performed, and the surgeon's opinion as to the usefulness of the 3D scanner as an aid for pre-operative body contour evaluation or as a tool to measure and document post-operative surgical results.

Exploration of Human Ageing by 3D-Laser Scanning Anthropometry

Henry LÖFFLER-WIRTH1,2, Alexander FRENZEL1, Markus LOEFFLER1,2,3, Hans BINDER1,2
1 Interdisciplinary Centre for Bioinformatics, Leipzig University, Leipzig, Germany;
2 LIFE, Leipzig Research Center for Civilization Diseases; Leipzig University, Leipzig, Germany
3 Institute for Medical Informatics, Statistics and Epidemiology, Leipzig University, Leipzig, Germany

Three-dimensional whole body scanning is an emerging technology for anthropometric assessment in epidemiological studies. We recently analysed 3D whole body scanning data of nearly 10,000 participants collected from the adult population of Leipzig. We were able to aggregate the body measures provided by the scanner into meta-measures, each representing one relevant dimension of the body shape, and to identify distinguishable clusters of body shapes. In the next step, we now study specifics of the so-called body types upon ageing to understand how meta-measures change during ageing. Further we investigate the distribution of participants in the body types with regard to stratification by age and gender. It becomes clear, that age significantly influences body shape, embodied by characteristic changes of the meta-measures representing systematic shifts in body proportions upon ageing, and by a marked developmental trajectory of body typing.

TECHNICAL SESSION 2: BODY SCANNING FOR APPAREL I

From 3D Scans to Haptic Models: Apparel Design with Half Scale Dress Forms

Susan P. ASHDOWN1, Arzu VURUSKAN2
1 Dept. of FSAD, Cornell University, Ithaca NY, USA;
2 Izmir University of Ecocomics, Izmir, Turkey

Any design process requires prototype development to test properties and perfect proportional or functional relationships before committing to production. Prototypes are also used to communicate concepts or solutions using limited materials and at an affordable cost. Architects have communicated their ideas using scaled models beginning as far back as medieval times. These models demonstrate their design ideas and help address functional issues in 3D. Scaled down dress forms used in fashion design are a more recent concept. One of the first uses of 3D body scanning for apparel in the early 2000s was to make dress forms based on body scans. In 2007, in a collaborative effort between Cornell University and Alvanon, a half scale form from body scan data was developed for educational use. This form is an exact reduction of a full scale form made from a body scan, and allows students to develop their designs with limited fabric, time commitment, and studio space. Students digitize the patterns they develop into a patternmaking CAD program and then scale them up to full scale. These forms have been used very effectively in product development and patternmaking classes at Cornell, and are now popular in schools around the world.

Further uses of half scale forms are being investigated for apparel research, creative pattern making, and pattern development for different body types. Half scale forms can be made in-house from body scans easily and economically. By using 3D body scan technology and transferring 3D digital data to sliced foam models or 3D printed models, custom half scale forms are developed. These forms have the potential to benefit both academia and industry.

From 3D Scan to Branding Journey

Nathon KONG
Nathon Kong, Montreal QC, Canada

Nathon Kong is a high-end label specialized in custom men's suits and shirts, introducing a modern-day flair to the long standing art of traditional tailoring. The company was founded 2 years ago and made itself known thanks to its innovative truck concept; a mobile boutique servicing the corporate downtown core, fully equipped with a built-in 3D scanner. For practical use, the application of the 3D scanner seeks to improve manufacturing by reducing the risk of human error. By leveraging biometric scanning technologies, the company is able to

retrieve high-precision measurements within minutes, helping their tailors construct completely personalized garments. The scanning tool soon became a staple for the Nathon Kong customer experience, answering the need for a more enjoyable shopping experience, and helped the brand define itself. Reviving an industry in desperate need of a fresh take, Nathon Kong's 3D scanner has become one of its most valuable marketing tool; able to communicate the brand's values for quality, innovation and expertise, all without compromising the timeless traditions of tailoring.

Not All Body Scanning Measurements Are Valid: Perspectives from Pattern Practice

Simeon GILL, Maryam AHMED, Christopher J. PARKER, Steven G. HAYES
The University of Manchester, Manchester, UK

To assume all body scanning measurements are valid for apparel product development is wrong. While human measurement forms the basis for product development and body scanning represents a significant development in the collection of human measurements, a distinction must be drawn between measurements suitable for product development (pattern cutting) and those required for the creation of sizing systems. The application of body scanning has largely focused on sizing surveys, the standards used in developing the technology are tailored toward surveys and subsequently measurements are often not defined in a manner suitable to developing products. This research began with analysis of product development practices and body scanning outputs to determine the suitability of body scanning to support existing methods of product development. Six methods of pattern development, established from previous research to represent the variation of approaches were selected, the measurements required for these methods were compared to measurement outputs from both a Size Stream and [TC]2 body scanner. Further analysis was made regarding the development of custom measurements for each scan system, to see if extra measurements could be defined to match those required or enhance the data used to drive the draft process. Whilst there are promising developments in automated pattern creation, there is little existing theory or clear understanding of pattern to person relationships to enable the full realization and embedding of these systems. As well as understanding the suitability of scan measurements for pattern development, this research also recommends further measurements which may improve the patterns' ability to accord with the individual size, shape and proportion of the wearer. This research shows that there are a range of measurements used for pattern making and these are not all available from existing body scanning systems. Key landmarks and measurements are identified and this research shows how body scanning technology can be developed to support existing and developing methods of pattern development.

POSTER SESSION

Innovative Applications of Fringe Pattern Projection

Dong HE1,2, Hailong CHEN1,2, Nan CHENG1, Bo PENG1, Menglong LIU1, Kaibing XIANG1, Xiaoli LIU2, Xiang PENG1,2
1 Shenzhen ESUN Co. Ltd., Shenzhen, China;
2 College of Optoelectronic Engineering, Shenzhen University, Shenzhen, China

The stereo vision by fringe pattern projection (FPP) is a popular active 3D imaging technology. In order to acquire the 3D images it is necessary to use the fringe analysis for the absolute phase map. With the aided of the phase map, the point correspondence can be identified, and the 3D images can be obtained precisely by triangulation strategy. Compared with other 3D imaging technology, such as spackle pattern projection or TOF (Time of Flight), FPP can efficiently acquire full color 3D images with high accuracy and density of the point cloud. Based on the FPP some dedicated 3D scanners such as the body scanner, the face scanner and the desktop scanner are developed by the ESUN Co. Ltd and Shenzhen University. This presentation will show the technical parameters and innovative applications of those 3D scanners. The ESUN+ body scanner can reconstruct 3D model of the whole body in a flash-speed scanning, performing with a cinematic detailed result. The body scanner has many potential applications in the field of anthropometry, fitness, fashion and virtual reality/augmented reality, etc. The ESUN+ desktop 3D scanner is operating in a fully automatic way and providing with a photorealistic result. The applications of ESUN+ desktop 3D scanner include e-shop and education. The ESUN+ face scanner can acquire the 3D image of whole face in a fast speed. The applications of this type of 3D scanner involves in electronic gaming, plastic surgery and virtual reality.

Evaluation of Body Surface Area Formulae Based on 3D Body Scans

Grzegorz REDLARSKI, Marek KRAWCZUK, Aleksander PALKOWSKI
Department of Mechatronics and High Voltage Engineering, Gdansk University of Technology, Gdansk, Poland

Human body surface area (BSA) is an established parameter for the calculation of chemotherapy drugs dosage, treatment of chronic hepatitis B, treatment of burns or for establishing a dosing regimen for antimicrobials. Although being a critical parameter, usage of modern 3D scanners, which would measure the exact BSA value, is often impossible in time-sensitive operations or for patients unable to withstand the scanning process. Therefore, over the last decades considerable research efforts have been devoted to development of simple formulae for BSA approximation. The formulae use a small number of state variables (weight, height, age, sex), which are intended to be easily obtained for every patient. The formulae parameters were estimated independently for isolated groups of subjects, which should rise suspicion whether any of the formulae used is indeed effective and safe for medical treatment. Here, we provide an extended analysis of 43 BSA formulae based on 152 patients scanned with a hand-held 3D scanner. Upon comparison of the real BSA values with estimations made by the formulae, we can conclude that most of the formulae exhibit a high relative BSA error, ranging from 9.83% to 43.27%.

Application of 3D Whole Body Scanning in Research on Human Body Surface Area

Grzegorz REDLARSKI, Marek KRAWCZUK, Aleksander PALKOWSKI
Department of Mechatronics and High Voltage Engineering, Gdansk University of Technology, Gdansk, Poland

Human body surface area (BSA) is one of the major parameters used in several medical fields. Its heterogeneity caused by individual human characteristics sustains a many-decades-long research on the matter. Today's technology allows to create exact body models in mere seconds. However, an extensive research that includes scanning people with major disfigurements or people suffering from diseases, which often prevent their mobility, requires a specific approach. Here, we present the entire scanning procedure and graphical processing methods used in investigation of changes in BSA in function of different anthropometric parameters. The Artec 3D Eva hand-held scanner has been used as the measurement device. We performed a total of five scans for every subject—four for each limb and one for the main body part. After a series of processing methods, the resulting body model can be further used as an accurate basis for BSA formulae investigation.

The Study on Fitting Dress' Comfort of Vocality Performer Based 3D Technology

Zifei LI, Huanyun WEI, Li ZHOU
College of Textile & Garment, Southwest University, Chongqing, China

From the angle of breathing movement, this paper takes the singer of the female singing as the object of the study, which is both focus on the research of the body breath status of performers before and after wearing tunic dresses and analysis of the relationship between performer's breathing movement and dress comfort. Base on this, the 3DCaMega human body scanning system is used to obtain the point cloud data of the performers in the same state to establish the virtual human body model. and according to the model data and comfortable level. Clo3D is utilized to optimize the structure of tunic fitting. Finally, Clo3D is used to simulate the fitting and to prove the comfort of the tunic dress,Making sure performers can gain excellent artistic singing effects.

Virtual Garment Intelligent Design

LinXu PAN1, Huanyun WEI2, Li ZHOU1,2
1 College of Textile & Garment, Southwest University, Chongqing, China;
2 Chongqing Biomass Fiber Materials and Modern Textile Engineering Technology Research Center, Chongqing, China

In period costume design of automation includes two main directions: Automated matching design of color and fabric based on clothing styles Human data research and the Paper sample automation generation. In the garments automation design, this first direction ignores the importance of fashion design; matching the garment elements from the mechanical and the regular angle. This article is based on it, to emphasize the intelligent research of creative design. Clothing style, fabric and color are selected by designer that is uncertain when the design goal had been set in the design process. This paper studies the intelligent method of design, and combine it with virtual reality technologies, creative intelligent design of virtual clothing. According to the research foundation, the clothes are divided into three stages. The first stage is subject determination, the second stage is integration of creative materials, the third stage is virtual design. The first stage, the ontological semantics of the design concept are established according to ontology theory. This is based on the basis of semantic information

retrieval and creative material foundation collection. The second stage, the decision tree model is adopted to integrate the creative materials resources. By definition of clothing variables that exist in clothing design, be able to simulate the creative design of subjective Angle. This method can establish the secondary decision (local decision) and improve the design process. The virtual design includes two aspects: 1 establishing the 3d human body model, 2 the virtual garment design. This method applies to the principle of clothing design. The third stage. This paper use 3d human body scanners to measure and build human body models, clothing design and presentation with CLO3D clothing design software.

Research on Optimal Efficiency of Data in Pattern Design

Caisen HUANG, Chunshan DENG, Li ZHOU
College of Textile & Garment, Southwest University, Chongqing, China

In the field of international manufacturing industry, innovative design and manufacturing technology for products have been developed from traditional labor technology to digitization and intellectualization. Whether it is emerging industry or traditional manufacturing industry, they have not been satisfied with the technical advantages provided by 2D technology and more 3D digital technologies have been integrated into them. With the advent of 3D era, 3D model construction, 3D digital imaging, 3D printing technology and so on have become a new impetus to promote product innovation and industry development.
Aiming at the situation that the research, about considering the optimal efficiency of the data in pattern design through the 3D manufacturing platform, is to be further improved, a research method to explore the optimal efficiency of the data form is proposed. Through tracing three-dimensional sizes of the human body, we selected the fifteen required body sizes of drawing pattern, which is designed with the help of the advantages of EMKO pattern and special human body measurement dimensions, from the data cluster. Moreover, we calculate the pattern type contrast score under different coverage ratio and carry on the optimal scale analysis and ROC curve fitting of the coverage ratio and pattern contrast score. Ultimately, according to the result of calculating and analyzing the coverage ratio and pattern contrast score and to the proof of experimental verification of 3D human body sample under the coverage ratio, the optimal circulation form of data in the process of pattern design can be determined.

Study of Fashion Accessories Design Based on 3D Printing Technology

Siyu CHEN, Huanyun WEI, Li ZHOU
College of Textile & Garment, Southwest University, Chongqing, China

This paper seeks to provide stylish designs of garment accessories with a kind of 3D printing technology data resource library on the basis of categorization and analysis of manufacturing principles and material properties of 3D printing technology. Styling for garment accessories includes internal styling and external styling. Through analyzing roles that 3D printing plays in spatial relations construction of garment accessories and in realizing these roles through utilizing internal processes and materials, 3D printing's functions in constructing the internal styling of garment accessories are highlighted; through analyzing its applications in functional additions and styling of garment accessories, 3D printing's applications in external styling of garment accessories are also reflected.

TECHNICAL SESSION 3: 3D SCANNING SYSTEMS

Active 3D Imaging Based on White Light Scanning: from Single Sensor to Sensor Networks

Xiang PENG1,2, Hailong CHEN1,2, Dong HE2, Xiaoli LIU1, Bo PENG2, Nan CHENG2
1 College of Optoelectronic Engineering, Shenzhen University, Shenzhen, China;
2 Shenzhen ESUN Co. Ltd., Shenzhen, China

Active 3D imaging based on white light scanning is a sort of efficient techniques which can digitize objects existed in physical world, and therefore to acquire 3D images of test targets. A light coding with a series of structured light patterns, for example, fringe patterns are usually applied for such a 3D imaging modality. A single optical 3D sensor based on fringe projection or 3D optical sensor network composed of multiple node sensors can be regarded as kinds of optical instruments that works on principle of computational imaging. In order to reconstruct a 3D image it is necessary to decode the fringe pattern to get the phase map that acts as special marks encoding each point of test object or scene, resulting in accurate determination of point correspondence. Once the homologous pairs identified precisely a 3D image can be obtained through a series of computations

using a stereoscopic vision theory. This paper will briefly reviewed the working principle of an optical digitizer based on the strategy of phase-aided active imaging (PAAI) and that of 3D sensor network composed of multiple PAAI sensors. In addition, many potential applications in 3D body scanning, face scanning, and heritage digitizing will also be addressed in this paper to show great potentials of 3D optical digitizer based on the PAAI strategy and PAAI-based optical measurement network. Both academic research at the Shenzhen University and commercialized products developed at the Shenzhen ESUN Co. Ltd. with number of patented technologies will be presented.

Portable Scanner of a 3D Surface of a Curvilinear Object

Konstantin KARAVAEV, Maxim TRUPHANOV
Elasizer, Kirov, Russia

The research covers the operation principles and structure-functionorganization of a specialized optical-electronic device for calculation of a volumetric object.

Here we present the results of our development of a special-purpose portable scanner of a 3D surface of a complete curvilinear object with a complex surface. Favorably compared with the analogs, our scanner features a high-precisioncalculation of a curvilinear object along with a compact and simple technical design which makes it easy to manufacture. We providedifferent technical solutions of our scanner based on novel original decisions which shuffle its technical features depending on the objectiveand enable to apply it in various ways. The above-said makes our scanner commercially attractive for certain tasks required in the market of customized items for individual application.

The general advantages of the designed scanner are several: the use of several passive optical-electronic sensors which are placed in preset fixed positions and factory calibrated with no additional settings necessary; use of commercially available electronic components; low time-consuming acquisition of parameters of a 3D surface; and ease of operation.

The experiments we conducted showed that, depending on the interrelated position of the device and the analyzed object, our device gives the calculation error of the 3D coordinates of about ±1.5 to ±2.5 mm.

TECHNICAL SESSION 4: BODY SCANNING FOR APPAREL II

Correspondence of Breast Measurements for Bra Design After Reconstruction Surgery

Krista M. NICKLAUS1,2, Jevon CHU1, Chi LIU1,3, Greg P. REECE2,
Fatima A. MERCHANT4, Michelle C. FINGERET2,5, Mia K. MARKEY1,6
1 Department of Biomedical Engineering, The University of Texas at Austin, Austin TX, USA;
2 Department of Plastic Surgery, The University of Texas MD Anderson Cancer Center, Houston TX, USA;
3 Apparel and Art Design College, Xi'an Polytechnic University, Xi'an, P.R. China;
4 Department of Engineering Technology, University of Houston, Houston TX, USA;
5 Dept. of Behavioral Science, The University of Texas MD Anderson Cancer Center, Houston TX, USA;
6 Dept. of Imaging Physics, The University of Texas MD Anderson Cancer Center, Houston TX, USA

Bra fit is a common quality of life problem for women with breast reconstruction. However, there is a lack of knowledge of how the changes in breast size and shape due to breast reconstruction surgery affect a woman's bra comfortability. There exists a unique opportunity to capture surgeons' knowledge of how breasts change after reconstruction and relay that information to clothing designers to aid designing bras for this patient population. Our goal is to investigate how to translate surgical knowledge about breast size, shape, and symmetry changes to quantitative data usable for bra design. We compared common measurements of the breast used by clothing designers to determine bra fit to standard clinical measurements used by surgeons for reconstruction planning. In consultation with a clothing designer and reconstructive surgeon, we determined 7 bra measurements and 8 associated fiducial points that can be localized on the type of clinical images that is widely used for documenting surgical outcomes. The measurements summarize the width, height, and projection of the breasts, as well as, the location of the breasts in reference to each other and to the torso. From our previously gathered database of 3D surface images of the torsos of 505 women who underwent breast reconstruction at The University of Texas MD Anderson Cancer Center, we selected a sample of 32 women who had implant-based reconstruction and had 3D images before breast surgery and images from at least three months after final implant placement. Using software developed by our team members at the University of Houston, a team member marked fiducial points, which were reviewed by an expert, on the pre-operative and post-operative images to calculate the bra

measurements. Using these fiducial points, we measure the size, shape, and symmetry changes in a manner that is directly translatable to clothing design from the pre-operative image to the post-operative image for each patient to identify common changes for implant-based reconstruction. Future work will lend insight into how different types of reconstruction affect bra fit and how bra design can be adapted to improve quality of life after breast reconstruction.

Reimagining Design of Golf Clothing: Addressing the Asymmetrical Pose
Arzu VURUSKAN1, Susan ASHDOWN2
1 Izmir University of Economics, Izmir, Turkey;
2 Cornell University, Ithaca NY, USA
One factor that can impact performance and comfort of athletes is clothing design. For many sports, the athlete performs a set of extreme movements that can be impeded or made uncomfortable because of clothing that does not accommodate such movements. The objective of this research is to create body forms in active positions to assist in the development of golf clothing for the active body. A Human Solutions Vitus Smart XXL body scanner was used to scan five professional golfers at different stages of a golf swing. Half scale dress forms in the active position were then prepared using these scans. The half scale forms developed in the golf swing pose are an effective design development tool to create golf clothing optimized for fit on the active figure. Wear tests and visual fit evaluations of prototype garments developed on these forms were conducted, comparing their fit and performance to when in a squatting pose and through the golf swing with the active pants developed in this research. As professional young golfers, all five participants stated that the idea of active pants and enhancing comfort through motion is as an important challenge to address.

Fostering Student Engagement: Participatory and Experiential Pedagogy for 3D Technology Integration
Caron PHINNEY
School of Fashion, Ryerson University, Toronto ON, Canada
Finding new ways of engagement for students with course material is a reoccurring goal among educators. Technological advancement and innovation in the apparel industry provides students with the opportunity to conduct contemporary research while allowing experimentation. The purpose of this paper is to examine the outcome of a student directed 3D body-scanning project – the focus of which was to conduct scan sessions with participants from the Faculty of Communication and Design at Ryerson University. Additionally, this paper examines how the successful integration of technology in the classroom is dependent on the pedagogical principles applied in the creation, development and implementation of course content.

A Method to Develop a Personalized Pattern of Pant from 3D Scanning Data
Junqiang SU1, Ying KE1, Bingfei GU2, Caiyuan KUANG3
1 School of Textile and Clothing, Jiangnan University, Jiangsu, China;
2 Fashion College, Zhejiang Sci-Tech University, Zhejiang, China;
3 College of Art, Jinling Institute of Technology, Jiangsu, China
A method was demonstrated to develop a personalized pattern of pant from 3D scanning data. There were three main steps to complete the purpose: 1) realization of individuality of a body; 2) description of distribution of ease allowance at characteristic features; and 3) a method to alter a basic pant pattern to develop a personalized one.

TECHNICAL SESSION 5: MEDICAL APPLICATIONS I

3D Body Scanning – An Important Tool for Digital Archiving of Cosmetic Surgery Procedures
David B. STEFAN1, David A. GILBERT2
1 Novaptus Systems, Inc. Chesapeake VA, USA;
2 The Hague Plastic and Cosmetic Surgery Center, Norfolk VA, USA
Background: At the end of 2002, a 3D whole-body white light scanner was introduced into a cosmetic surgery practice in Norfolk, Virginia. The stated purpose was to investigate this device as an aid for evaluating body contouring procedures. For the first time, the surgeon could pre-operatively scan a patient, measure “body areas of interest,” and examine in detail the patient’s 3D body contours to help plan for the pending surgical procedure. Multiple, custom designed measurement templates were then applied to the 3D body model to extract measurements pertinent to the surgical procedure. The pre-operative 3D body model was stored. Post-operative

scans of the patient would then be taken periodically, and measured with the same measurement templates. The difference in measurements, including volume and surface area document the physical changes of patient's body resulting from the procedure. Many cosmetic surgery patients return for additional procedures over the course of years. The patient's 3D digital archive provides the surgeon with the ability to consult previous 3D body models and evaluate the measurement changes of past procedures. These unique insights, combined with a current 3D scan and traditional medical information form a contiguous and robust foundation for assessing the pending surgical procedure.
Methods: Three case examples are presented. Case 1 considers multiple cosmetic procedures performed in a close succession and the 3D scans and measurement templates used for pre-operative and post-operative evaluation. Case 2 presents an example 3D body scans of sequential cosmetic surgical procedures to replace and rebuild the left and right breasts of a subject. Case 3 involves multiple cosmetic procedures performed on the same patient over a period of years. In each case, the patient's 3D digital archive played an important role in documenting each surgical procedure and provided a platform to evaluate the contours of the patient for the pending surgery.
Discussion: A 3D whole-body scan is an independent entity. It represents the accurate physical appearance of the subject standing in the scan chamber as of the date and time of scan acquisition. A cosmetic surgery patient may undergo multiple procedures at once, such as breast reduction and abdominoplasty. The result of each procedure can be measured by applying separate customized measurement templates to the post-operative 3D body model. The patient may also undergo a sequence of procedures over time. Each post-operative 3D body model can be evaluated independently. The entire set of pre-operative and post-operative 3D body scans form a historical 3D digital archive and can be appended to the traditional patient medical record.
Conclusion: The utility of a 3D whole-body scanner is in its ability to create an accurate 3D body model of the subject within the scan chamber, thereby creating a permanent 3D record once stored. A "clean" 3D scan documents the subject's physical body. Measurements can be extracted at any time as appropriate, but the archived 3D body model is the important record. Subsequent body scans can be measured and compared to the initial body scan. Many cosmetic surgery procedures result in immediate physical changes to the body. Each post-operative scan documents these changes. Successive post-operative scans form the patient's 3D digital archive. This archive can serve as the basis for further surgical planning, validating surgical results, or can be used as a tool for independently assessing surgical outcomes.

Quantitative Analysis of Localized Changes in Breast Shape

Audrey L. CHEONG1, Gregory P. REECE2, Mia K. MARKEY3,4,
Michelle C. FINGERET2,5, Fatima A. MERCHANT1,6
1 Department of Electrical and Computer Engineering, University of Houston, Houston TX, USA;
2 Department of Plastic Surgery, The University of Texas MD Anderson Cancer Center, Houston TX, USA;
3 Department of Biomedical Engineering, The University of Texas at Austin, Austin TX, USA;
4 Department of Imaging Physics, The University of Texas MD Anderson Cancer Center, Houston TX, USA;
5 Dept. of Behavioral Science, The University of Texas MD Anderson Cancer Center, Houston TX, USA;
6 Department of Engineering Technology, University of Houston, Houston TX, USA

Breast reconstruction surgery is an integral part of breast cancer treatment for many patients and has been shown to positively influence patients' psychosocial adjustment and quality of life. Three-dimensional (3D) visualization and quantification of the breast for different types of reconstruction procedures during the reconstruction process can allow for a better understanding of the changes in breast shape. The reconstruction process, which involves multiple procedures, can take as long as 18 - 24 months, and the breasts can change shape throughout this period. In this study, we present a novel approach for monitoring and quantifying changes in breast shape using 3D surface images of the torso in conjunction with surface normal measurements. The results of this study can help provide information to physicians and patients about the dynamic changes in breast morphology occurring at different stages of the reconstruction process. Additionally, this information may assist in pre-treatment surgical planning and training. In our approach, we compare the surface normal values of different regions of the breasts at different time-points using the Bhattacharyya distance, which measures histogram similarity. Results are shown for 17 patients who underwent autologous reconstruction, 14 patients who underwent implant-based reconstruction, and one patient who underwent a mixed reconstruction. Using the proposed method, we were able to evaluate changes in the 3D surface images of reconstructed breasts relative to the 3D images of preoperative breasts.

Analysing Single Photographic Images using Shape-From-Shading to Quantify Human Breast Profiles

Harvey MITCHELL
School of Engineering, University of Newcastle, Newcastle, Australia

Inspections of the three-dimensional shape of the human breast for various medical and para-medical purposes may be undertaken by visual observation of the breasts or of photographs of them, or by laser scanner measurement. It is proposed here that useful quantitative breast shape information may also be deduced by numerical analysis of a single digital photograph of the breast, using the principle of extracting an object's shape from image shading.

Shape-from-shading (SfS) is a method of deducing shape from the reflectance levels in a single photograph of an object. If an object has smooth physical texture and if it has light even colouring, the SfS technique is a possible means of obtaining the three-dimensional surface shape. SfS is appealing because of its one advantage: simplicity. SfS needs no special equipment, and involves the numerical analysis of a single digital photographic image, which is discussed in this paper.

Although SfS is restricted to objects of invariant colour texture and simple physical texture, it is suggested that those drawbacks may be tolerated for the measurement of some external surfaces of the human body, i) because the human skin surface colour is usually plain, ii) if surfaces are not too convoluted, and perhaps even iii) where some prior surface shape information can be assumed. It is envisaged that these three conditions may occur along certain profiles across the breasts. Along those profiles, a triflingly simple mathematical solution to SfS is available. An approach which is found to be workable in cases of measurement of breast-like shapes is proposed, and some preliminary and exploratory but informative tests of the technique are reported, with some accuracy tests of the technique on known shape objects and preliminary breast profile measurements. Motivation for further testing and development depends on its prospects for medical use in breast measurement.

Three-Dimensional Stereophotogrammetric Analysis of Adults Affected by Dravet Syndrome

Valentina PUCCIARELLI1, Elena PIAZZA2,3, Francesca RAGONA2, Daniele GIBELLI1,
Tiziana GRANATA2, Claudia DOLCI1, Chiarella SFORZA1
1 Dipartimento di Scienze Biomediche per la Salute, Università degli Studi di Milano, Milano, Italy;
2 Dipartimento di Neuroscienze Pediatriche, Istituto Neurologico C. Besta, Milano, Italy;
3 Dipartimento di Neuropsichiatria Infantile, Istituto Neurologico C. Mondino, Pavia, Italy

Dravet syndrome (DS) is a rare and severe form of epilepsy, associated with mutations of SCN1A gene, encoding for the sodium channel voltage-dependent Nav.1.1. Epilepsy appears in the first year of life in an otherwise healthy infant; seizures may be focal, unilateral or generalized and facilitated by fever. The disease is progressive and during its course neurological signs change, comorbidities appear and cognitive deficits become highly disabling. Currently, early diagnosis of the syndrome is possible, nevertheless, up today, many adult cases remain not yet diagnosed, especially if the clinical childhood history is fragmented. A preliminary stereophotogrammetric morphometric evaluation of facial soft tissues of six Dravet syndrome patients (3 males, 3 females, aged between 16 and 37 years) was performed with the aim of facilitating the recognition of the syndrome also in adult patients and identifying morphological common facial features in affected patients.The three-dimensional coordinates of a set of facial landmarks, identified on the faces of the patients, were collected and compared to the coordinates of a group of reference subjects, paired for age, sex and ethnicity and previously acquired. From these coordinates, linear measurements were performed and z-scores were computed. The analysis of z-scores showed that patients had a reduction of mandibular ramus length (z-score = -1.7) and a consequent reduction of the ratio between the anterior and posterior facial heights (z-score = -1.3). Furthermore, 4 of the 6 patients had a reduction of the labial philtrum width. Despite the reduced number of patients, this preliminary report shows the presence of dysmorphic features among them. These results could give a support for a correct diagnosis in adult patients and could indicate a possible role of SCN1A or close genes in facial morphogenesis.

TECHNICAL SESSION 6: 3D FULL BODY SCANNING SYSTEMS I

Unification Process for Uniforms with Use of 3D Body Scanning

Łukasz MARKIEWICZ1, Elżbieta MIELICKA2, Gabriel WASILEWSKI3,
Krzysztof MULARCZYK1, Lidia NAPIERALSKA2, Robert SITNIK1
1 Warsaw University of Technology, Mechatronics Faculty, Warsaw, Poland;
2 Textile Research Institute, Knitting and Clothing Research Department, Lodz, Poland;
3 Medcore Sp. z o.o, Warsaw, Poland

There is much to be done to improve fitting quality of uniforms used by uniformed services in Poland. The main reasons of badly fit uniforms are inconsistency of uniform sizes in each of the services and statistical differences in body measures since the last national population survey. In order to develop the new statistics of body sizes and size charts, 3D measurements of body shape have been carried out on a large scale. Additional goal was to develop the OGX|MMS measurement system which could be used by the services in the future for periodic monitoring.

The developed system's working principle is structured light projection. The scanning system is composed of four measurement heads, each containing two 3D scanners placed vertically. Due to a spectral separation of the scanners, all measurement heads can perform data acquisition at the same time. Total measurement time is approximately 3 s. The result is a 3D cloud of points which represents the measured body surface with resolution of 1 mm and accuracy below 0.3 mm.

New algorithms were also developed for extracting anthropometric measurements from acquired body models. During the project 34 types of measurements were carried out to enable the creation of new size charts. The processing path for the measurements included filtration and measurement noise elimination, 3D segmentation, location of anatomical landmarks and calculation of body measurements (arc lengths, girths and linear sizes). A commercial Human Solutions laser line-based 3D measurement device was used as a reference for the automatically extracted measures. Comparative analysis between the two 3D scanning methods and manual measurements was performed. Manual measurements were taken according to the ISO 7501-1, ISO 8559, and EN 13402 standards. 26 features which can be used for clothing design were chosen for the analysis.

The efficiency of the scanning process was tested in a real-life environment. The main advantage of the 3D scanning method compared to the manual measurements is the ease and speed of the process and the ability to repeat measurements of the specific features using the stored virtual model.

TECHNICAL SESSION 7: ANTHROPOMETRY & SCAN DATA PROCESSING

Automatic Detection of Body Landmarks in Human Body Scans – Lower Limb Analysis for Biomedical and Footwear Applications

Alessandra TURSI, Gregorij KURILLO, Ruzena BAJCSY
University of Berkeley, Berkeley CA, USA

This paper presents a pilot study of detection and deformation tracking of 3D body landmarks. In particular, the primary goal of this research was to develop methodology for automated design of individualized 3D printed ankle and foot orthoses for persons affected by Duchenne and Becker muscular dystrophies. The results of this study could have further implications on the design of not only the static orthoses but also active exoskeleton systems and general body deformation tracking.

Although body scanners are becoming increasingly popular in the recent years, due to new advances in 3D sensing, there are several outstanding issues related to the automated extraction and standardization of body measurements. Modern body scanners are able to virtually reproduce body shapes with an extreme accuracy. However, the result of a body scan is an indistinct 3D mesh, usually without any easily recognizable body landmarks that could provide consistent and robust measurements of the anthropometric parameters related to the particular body part. Although some of the body scanning software packages provide automatic or semi-automatic segmentation and extraction of different body measures, the algorithms are proprietary and do not easily compare between different systems.

In summary, the important open questions are the following: 1) how to uniquely recognize the same points on scans from different people in order to extract comparable measurements, 2) how to extract the same measures starting from two body scans of the same person, acquired and processed by different body scanning hardware. This paper first briefly describes the state of art in body scanning and body measurement extraction while

focusing in particular on lower limbs. The lower limbs are one of the more challenging body parts for scanning as there are very few easily recognizable body landmarks. Majority of the landmarks described in the literature require palpation to locate them and therefore cannot be detected purely from visual data. Presented analysis is focused on first obtaining 3D scans of the foot, ankle and lower leg in different configurations (e.g. flexion/extension) using a custom-developed contraption that allows for scanning in a secure static position. In our tests, we used the most common landmarks reported in medical and design literature. The scans obtained in the different configurations are then aligned based on the landmarks while the algorithm extracts the skin surface deformation in different cross-sectional plains. Based on the change in curvature, it is possible to extrapolate this information across the surface of the lower limb to estimate how much soft tissue deformation is exhibited during the observed configuration change.
By quantifying the deformation across the surface of the lower limb, it is possible to determine the sections of the limb where the deformations are small. This information is crucial for customized design of biomedical and footwear products. For example, the areas that exhibit low deformation/movement can be put in close and more rigid contact with the orthosis, while the areas with large deformation require additional padding and softer materials to prevent skin irritation and discomfort.

Torso Shape Extraction from 3D Body Scanning Data using Automatic Segmentation Tool
Ola AHMAD1,2, Philippe DEBANNÉ1,2, Stefan PARENT2, Hubert LABELLE2, Farida CHERIET1,2
1 Polytechnique Montréal, Montreal, Canada;
2 CHU Saint-Justine, Montreal, Canada
The automatic and standardized extraction of the torso shape from 3D body scanning data has an important role in biomedical applications. In scoliosis clinics, the asymmetry analysis of the 3D scoliotic trunk shape relies on a prior cropping of the regions corresponding to the arms and neck. At Sainte-Justine Hospital, a system of four optical digitizers (Capturor II LF, Creaform Inc.) is used to scan the body of scoliosis patients. At present, the cropping of the trunk shapes is a manual process and is therefore operator-dependent, time-consuming and can affect the reliability of subsequent trunk asymmetry analysis. In addition, the inferior portion of the trunk (pelvic region) includes noisy geometric features that are due to the patient's lower body clothing and are irrelevant to the study of scoliotic trunk shape deformations. In this paper, we present a robust and efficient tool to extract the meaningful torso regions based on automatic segmentation. The 3D body scanning system provides a 3D triangulated mesh of the shape accompanied by an RGB color map of the texture. An anatomical landmark placed at the midpoint of the posterior-anterior iliac spines (MPSIS) prior to the acquisition determines the separation level between the pelvic region and the rest of the torso (i.e. the lumbar and thoracic regions).
We propose a two-phase segmentation algorithm. In the first phase, a skin-color model is used to separate the pelvic region from the other portions of the torso. The second phase separates the arms and neck regions using relevant geometric features captured by a spectral representation of the shape.
We tested our algorithm on a dataset composed of 56 scoliotic body shapes scanned in neutral standing and lateral bending postures by comparing the torsos cropped automatically versus manually by an operator. The results show that our algorithm achieves a 0.95 (± 0.04) degree of overlap, in terms of the average Dice similarity measure, between the extracted torso shapes and their ground truth counterparts. The proposed automatic segmentation method thus constitutes a useful tool to include in the 3D body surface scanning systems used in scoliosis clinics.

TECHNICAL SESSION 8: 3D TECHNOLOGIES FOR APPAREL I

An Exploratory Study of Clothing Fit for Male Consumers: Body Type, Clothing Fit and Anthropometric Scan Data
Osmud RAHMAN, Henry NAVARRO
Ryerson University, Toronto ON, Canada
It is evident that a poor-fitting garment would lead to consumers' dissatisfaction, return of merchandise, and financial losses, whereas a well-fitting garment can provide both physiological comfort (e.g., ease of movement) and psychological comfort (e.g., aesthetically acceptable) to the wearers. Therefore, it is important for the fashion practitioners to understand the relationships between the body type and garment fit in order to produce desirable and good fitting garments as well as to establish a relevant and updated Size Chart for today's consumers. However, there have been limited research literature have examined on the relationship of men's

body type and clothing fit. As Chattaraman et al. assert, “Although both men and women experience fit dissatisfaction, scholarly research has almost exclusively focused on women, leaving a critical gap in the research on men’s fit issues and preferences.” In order to understand the body size and garment fit of men, [TC]2 3D Body Scanner will be used to collect anthropometric data from male participants in order to develop different size charts for diverse body types (e.g., oversized, muscular, average, slender). In short, body scanning has been widely used in both academia and industry to provide accurate assessment of body measurements and generate three-dimensional images of participants’ external body shape. In addition to body scan, an in-depth interview will be employed to gain a deeper understanding of how men perceive and evaluate clothing from three different perspectives – aesthetic, function and emotion. Through this study, we believe that we can (1) identify some prevalent body types of men including the waist-to-height ratio, neck-to-arm ratio, and arm-to-height ratio; (2) better understand the relationships among the Body Mass Index (BMI), garment ease, and perceived body image; and (3) perhaps a greater variety of garment fits can be offered to the short men who have been underserved. The results of this study will provide insights and information related to short male consumers’ shopping behavior, and consumption experiences.

NATO Research Task Group: 3D Scanning for Clothing Fit and Logistics

Allan KEEFE1, James KUANG2, Hein DAANEN3
1 Defence Research and Development Canada - Toronto Research Centre, Totonto, Canada;
2 Department of National Defence, Canada;
3 Vrije University Amsterdam, Amsterdam, The Netherlands

Military organizations require accurate information on the relationship between body size and shape to ensure proper fit of clothing and personal equipment. From an operational perspective, proper fit is essential for soldier clothing and equipment ensembles to function as designed, allowing optimal mobility, comfort and protection from environmental and ballistic threats. Meeting these requirements is challenging, as operational uniforms and ceremonial wear must be provided to all military members.

Custom tailoring is provided for individuals of extreme body size, but this practise is expensive and undesirable. Additionally, secular changes in body size, and increasing ethnic diversity and presence of women in operational trades, including combat arms, has presented a challenge to military departments responsible for clothing specification, procurement and issuing.

In response, the North Atlantic Treaty Organization Science and Technology Organization (NATO STO) has recognized the potential of 3D body scanning as a tool to rapidly acquire 3D anthropometry and body shape data to support clothing design and issuing. This has led to the establishment of NATO Research Task Group (RTG) HFM-266: 3D scanning for clothing fit and logistics. Currently, this Task Group is comprised of 9 member nations and one ally. The outcomes of this Task Group will serve to provide a better understating of the application of 3D body scanning technologies for military clothing and equipment application and inform the development of clothing sizing standards across NATO countries.

Online Virtual Fit is not yet Fit for Purpose: An Analysis of Fashion e-Commerce Interfaces

Monika JANUSZKIEWICZ, Christopher J. PARKER, Steven G. HAYES, Simeon GILL
The University of Manchester, Manchester, UK

To unify the methodology of Virtual Fit platforms and allowing cross platform integration of 3D Body Scanning, the current Virtual Fit platforms need to be assessed in terms of their size recommendation approach and user interaction. Digital data, interactivity, and internet technology are changing the ways we interact in online shopping, with the Virtual Fit platforms having great potential to increase retail engagement and market share. This will support online purchasing activities while minimising the perceived risk in garment returns due to the poor sizing fit information.

Current research has focused on the analysis of computer modelling techniques, avatars, cloth, fabric draping simulations, and customer behaviour / aesthetic impact in the online domain. From a technical perspective, these investigations offer an interesting insight, although do not address issues of implementation or customer attitude. Therefore, to judge the current and potential impact of such technologies, it is important to understand 1) how they are being enacted online, 2) the Interaction Design elements of the user journey, 3) the application (or lack thereof) of mathematical models, and 4) how such interfaces are embedded within websites. Once these four key questions have been answered a greater understanding of how 3D Body Scanning and Technologies integrated into e-Commerce and Virtual Fit platforms in the consumer market may be reached.

Through analysis of nine leading Virtual Fit platforms, the persona of a single female dress form was used to

work through the customer journey. Through this, screen shot data captured along each stage in relation to the four research questions listed above. Following this, the study utilised content analysis structure with NVivo as a qualitative thematic analysis tool.
This study found that despite a large number of platforms using virtual fit technology, only a handful companies exist that provide such technology and interfaces; often based upon subjective 'previous purchases' rather than scientific prediction. This issue is made more complicated in how subjective measures such as personal perception of one's body is required (e.g. what size are you), besides body shape; a concept shown to be 'broken' and not fit-for-purpose. In addition, many of the technologies use limited and often misinterpreted body measurements, the impact of which is explored in greater detail within the paper. This study contributes to the understanding of the information required from users by virtual fit platforms, and the understanding of the output as presented by virtual fit platforms. The research goal is to contribute to knowledge as a potential guideline for any future projects in virtual fit and to help direct body scanning developments to better support these platforms.

Fast, Portable and Low-Cost 3D Foot Digitizers: Validity and Reliability of Measurements
Alfredo BALLESTER, Ana PIÉROLA, Eduardo PARRILLA, Mateo IZQUIERDO, Jordi URIEL,
Beatriz NÁCHER, Vicent ORTIZ, Juan C. GONZÁLEZ, Álvaro F. PAGE, Sandra ALEMANY
Instituto de Biomecánica de Valencia, Universidad Politécnica de Valencia, Valencia, Spain
This paper presents partial results of a larger validation study of two innovative products based on Data-driven 3D Reconstruction (D3DR) technology: a smartphone app, Avatar3D, and a portable booth, DomeScan. This study quantifies the reliability (Standard Error of Measurement, SEM, Intra-class Correlation Coefficient, ICC) of the automatic foot measurements elicited by these solutions and compares it to traditional anthropometry and to a commercial laser foot scanner. Moreover, it assesses the compatibility (systematic bias) of measurements among these techniques. The results show that, for the six measurements assessed, D3DR is as reliable as high resolution 3D scanners and more reliable than manual measurements made by an expert. Due to its lower cost, speed and portability they could be more suitable for retail and home environments than actual 3D scanners.

TECHNICAL SESSION 9: MEDICAL APPLICATIONS II

Third-Based Facial Similarities and Differences of Monozygotic Twins: A Stereophotogrammetric 3D Assessment
Valentina PUCCIARELLI1, Daniele GIBELLI1, Danilo DE ANGELIS2, Pasquale POPPA2,
Marco CUMMAUDO2, Marina CODARI3, Claudia DOLCI1, Chiarella SFORZA1
1 Dipartimento di Scienze Biomediche per la Salute, Università degli Studi di Milano, Milano, Italy;
2 LABANOF - Laboratorio di Antropologia e Odontologia Forense, Sezione di Medicina Legale,
Dipartimento di Scienze Biomediche per la Salute, Università degli Studi di Milano, Milano, Italy;
3 Unit of Radiology, IRCCS Policlinico San Donato, San Donato Milanese, Milan, Italy
The genetic background of the craniofacial development is a sensitive topic: in this context twin studies have had a relevant role as they allow to understand the effect of genes on the anatomical variability observed in the population. In particular, monozygotic twins (MZT) share the same DNA and allow to evaluate the genetic component of a specific morphology. In order to understand the similarities and differences on the facial morphology of MZT in different portions of the face, a third-based, superimposition approach was applied to the 3D facial scans of 10 couples of MZT. The experimental subjects were acquired through a stereophotogrammetric system, after the identification of a set of reference landmarks on their facial surfaces. The landmarks were used to segment facial areas of interest from the 3D reconstructions and to subdivide them into thirds, according to the territories of distribution of trigeminal branches for somatic sensitivity. The left and right upper, middle and lower facial thirds of each MZT couple were pairwise superimposed and the root mean square (RMS) point-to-point distances were automatically calculated. Data were statistically analysed through a two-way ANOVA, setting the level of significance at 5%. Post-hoc tests were performed with the necessary reductions in the degrees of freedom. Results revealed statistically significant differences among thirds ($p < 0.05$), while no differences were found for facial sides ($p > 0.05$) or for the third x side interaction ($p > 0.05$). Post hoc tests showed statistically significant differences between the upper and the lower facial thirds, and the middle and lower facial thirds ($p < 0.05$), with the middle and lower thirds being the more different between the couples. In conclusion, stereophotogrammetric techniques can be valid instruments to analyse the facial morphology of MZT. The acquisition procedure is easy to perform, fast and free from risk, being suitable to

obtain multiple subsequent 3D reconstructions. These reconstructions can be superimposed and locally analysed in order to provide an anatomically-based, detailed description of the most similar and different facial areas, useful for the evaluation of the genetic components of a specific morphology.

Three-dimensional Thermal Imaging in Medicine

Adam CHROMY, Ludek ZALUD
CEITEC - Central European Inst. of Technology, Brno University of Technology, Brno, Czech Republic

The digital medical thermal imaging is valuable qualitative tool for detection of inflamed or necrotic areas, but it lacks the ability of quantification. The new 3D scanning system RoScan composed from robotic manipulator, laser scanner, color camera and thermal imager is presented, extending medical thermal imaging with possibility of quantification, allowing specific ROI selection and bringing higher thermal resolution in resulting outputs. It helps to solve the current problem of medical quantification, which permeates through the many medical sectors. The advantages of RoScan are demonstrated on experiments, which shows the benefits of proposed device.

A Survey of Measurement Templates used for Assessing Pre-Operative Body Contours and Evaluating Cosmetic Surgery Results using a 3D Whole-Body Scanner

David B. STEFAN1, David A. GILBERT2
1 Novaptus Systems, Inc. Chesapeake VA, USA;
2 The Hague Plastic and Cosmetic Surgery Center, Norfolk VA, USA

Background: A 3D whole-body scanner has been utilized at a cosmetic surgery practice in Norfolk, Virginia since 2002. Pre-operative and post-operative scans have been taken of many patients that have undergone various cosmetic surgical procedures. Through trial, error and analysis, various measurement templates have been designed as an aid for the surgeon to assess the pre-operative body contours and to evaluate the post-operative results of common cosmetic procedures. This paper presents measurement templates that have been found to be useful for breast augmentation, breast reduction, abdominoplasty and thigh-lift surgical procedures.

Methods: Manual measurements have traditionally been used to evaluate the body contours of the pre-operative patient. These are typically of linear and circumferential nature. Many of the manual measurements made by the surgeon are replicated within the scanner measurement software. These can be selected and programmed into a measurement template, which can then be applied to the patient's 3D body model to automatically extract the desired information. The scanner measurement software can produce multidimensional measurement information such as surface area and volume. Such measurement tools were previously unavailable. There are many measurements provided by scanning software that are beneficial to enhance the pre-operative evaluation, perhaps too many. These include linear contours, the height of certain measurements and uncommon circumferential measurements. The measurement templates presented are a result of experience. Case 1 and Case 2 detail the measurement template used for evaluating breast augmentation and breast reduction procedures. Case 3 is an example of the measurement template used for evaluating an abdominoplasty procedure. The measurements utilized for abdominoplasty center around the mid-section of the body. Case 4 is an example of the template used for evaluating a thigh-lift. The measurements utilized are focused on the lower half of the body.

Discussion: Applying procedure-specific measurements to a pre-operative 3D body scan can help detect and quantify existing asymmetries. These asymmetries may be corrected during the surgical procedure through proper planning. Breast augmentation, reduction, abdominoplasty and thigh-lift surgical procedures have immediate impact on the body. These changes can be measured longitudinally as patients return for post-operative visits. The effects of edema (swelling) can be documented with each post-operative 3D body scan. The edema usually abates within six months and the 3D body scans thereafter can be compared with the pre-operative 3D body scan to quantify the physical changes brought about by the surgical procedure. Changes in volume can be reviewed against the weight of the actual amount of tissue removed in cases of breast reduction, thigh lift, or abdominoplasty. In the case of breast augmentation, changes in post-operative bust volume can be compared to the size of the breast implants inserted.

Conclusion: The measurement templates used to document the cosmetic surgical procedures discussed have evolved over time. They are in no way final or complete, but they have added considerable multidimensional insight into evaluating pre-operative body contours and documenting any pre-existing asymmetric conditions. Applying these templates to post-operative 3D body scans quantifies the physical changes brought by the surgical procedure, including the correction of detected asymmetries. Moreover, the series of pre-operative and post-operative 3D body scans form the patient's 3D digital archive. As new measurements are added to the

existing measurement templates, they can be applied to 3D body models of past surgical procedures for investigation and validation.

Mirroring Procedures for the Assessment of Asymmetry of Different Anatomical Structures of the Cranium: A Protocol Based on 3D-3D Superimposition

Daniele GIBELLI1, Valentina PUCCIARELLI1, Marina CODARI2,
Luca PISONI1, Claudia DOLCI1, Chiarella SFORZA1
1 Dipartimento di Scienze Biomediche per la Salute, Università degli Studi di Milano, Milano, Italy;
2 Unit of Radiology, IRCCS Policlinico San Donato, San Donato Milanese, Milan, Italy

The assessment of asymmetry has always represented one of the most relevant field of research in anatomy, with several applications in reconstructive and aesthetic surgery. This study aims at exposing an innovative protocol for the assessment of asymmetry of cranial structures based on 3D-3D superimposition and mirroring procedures. Five patients who underwent a head CT scan were selected. Three anatomical structures were automatically segmented through ITK-SNAP free software: maxillary sinuses, zygomatic bones and the petrous portion of both temporal bones. The left structure was then reflected automatically into the right image and superimposed over the contralateral one according to the least point-to-point distance on the entire surface. RMS (root mean square) distance was then automatically calculated for each superimposition. In addition, a chromatic map of superimposition was generated, showing the most variable areas between the two sides. Possible statistically significant differences in RMS value according to the three anatomical structures were assessed through one-way ANOVA test ($p<0.05$). On average, RMS values for maxillary sinuses, zygomatic bones and petrous part of temporal bones were respectively 1.00 mm (SD: 0.27 mm), 0.70 mm (SD: 0.34 mm) and 1.26 mm (SD: 0.17 mm). A significant difference among the symmetry of the three analysed structures was found ($p<0.01$, ANOVA). A novel approach for the assessment of anatomical asymmetry is suggested, based both on a morphological and a quantitative evaluation of differences between the right and left side skull bones.

TECHNICAL SESSION 11: BODY SCANNING WITH CLOTHES ON

New Improvements to Millimeter-Wave Body Scanners

Douglas MCMAKIN, David SHEEN, Thomas HALL, Jonathan TEDESCHI, A. Mark JONES
Pacific Northwest National Laboratory, Richland WA, USA

The Pacific Northwest National Laboratory (PNNL) pioneered the development of the millimeter-wave body scanner in the 1990s. PNNL licensed this technology to companies in the security and apparel industries. Millimeter-wave body scanners are ideally suited for applications in high-traffic areas such as airports and retail spaces because the scanners are extremely fast and do not require people to remove outer garments. Since low-power millimeter-waves are non-ionizing, the scanners present no health hazards during scanning operations. The resolution of the resulting imagery enables highly accurate threat detection (for security) and body measurement (for apparel). PNNL is actively engaged in the research and development of methods to continue to improve this technology. This paper will discuss the underlying millimeter-wave scanner technology and new developments that improve the image quality of these systems. New developments in the use of millimeter wave scanning for accurate location identification in radiation therapy may also be utilized.

BodiData's Multi-Sensors Handheld 3D Body Scanner

Tuoc LUONG, Albert CHARPENTIER, Michael BOYLAN, Young HARVILL
BodiData Inc., Sunnyvale CA, USA

The current state of 3D body scanning technology has limitations with respect to size, mobility, clothing constraint and accuracy.
BodiData’s patented multi-sensor handheld 3D body scanner meets these needs as a small, portable, system capable of scanning a fully clothed individual and extracting the body measurements accurately. BodiData has built the largest 3D body dimensions database, which contains over 1M individual scans and is used to support a novel progressive scanning algorithm.
The BodiData handheld scanner is designed as a retail accessory that easily attaches to the backside of a tablet, an innovative bracket concept securely holds the tablet to the scanner - no wires are needed.
This ultra-portable lightweight device requires minimal setup and can be used in a variety of retail settings bringing immediate benefit to both the customers and retailers as dimensionality data can be obtained to find a

matching garment.
The system is designed to measure a fully clothed human body in less than 2 minutes and accurate body measurements are acquired by integrating data from the optical depth camera and radar system.
The scanner is powered with Li-ion batteries that provide up to 5 hours of cumulative scanning. The off--the-shelf batteries can be quickly swapped out to support extended scanning sessions if needed, there is no need to take the scanner out of service to wait for recharging.
The optical depth camera, having a wide-angle view and large depth of field captures range information to the clothed portion of the body and is accurate to within +/ - 2mm.
During active scanning, the low-power radar system that operates in the 57-64GHz unlicensed ISM band uses highly directional antennas to make a precise distance measurement to the body. At 40cm away, the radar resolves distances to a roughly 9cm 2 area of the body. In a typical scan, the radar will collect and process over 2 Million pieces of range data.
An advanced inertial and positioning system is utilized to keep track of the unit in space as the operator scans the individual. The scanner module contains an on-board processor that combines the output from the optical system, the radar system and a suite of other sensors and transfers the related pieces of data to the tablet for additional processing, rendering and measurement extraction.
Customer privacy is assured, as the device only uses scan data from a fully clothed person and the radar is a range finding device and will not resolve detailed images of the body. The full set of data is used to build a physical model of the person to ultimately drive a garment-fitting engine to produce a sizing recommendation. While sizing is the primary role of the scanner, the retailer can also use integrate the system with a customers POS system to provide additional value.

Towards Automatic Human Body Model Fitting to a 3D Scan
Alexandre SAINT1, Abd El Rahman SHABAYEK1,2, Djamila AOUADA1,
Björn OTTERSTEN1, Kseniya CHERENKOVA3, Gleb GUSEV3
1 Interdisciplinary Centre for Security, Reliability, and Trust, Univ. of Luxembourg, Luxembourg;
2 Computer Science department, Faculty of Computers and Informatics, Suez Canal University, Egypt;
3 Artec Europe S.à.r.l., Luxembourg, Luxembourg
This paper presents a method to automatically recover a realistic and accurate body shape of a person wearing clothing from a 3D scan. Indeed, in many practical situations, people are scanned wearing clothing. The underlying body shape is thus partially or completely occluded. Yet, it is very desirable to recover the shape of a covered body as it provides non-invasive means of measuring and analysing it. This is particularly convenient for patients in medical applications, customers in a retail shop, as well as in security applications where suspicious objects under clothing are to be detected. To recover the body shape from the 3D scan of a person in any pose, a human body model is usually fitted to the scan. Current methods rely on the manual placement of markers on the body to identify anatomical locations and guide the pose fitting. The markers are either physically placed on the body before scanning or placed in software as a postprocessing step. Some other methods detect key points on the scan using 3D feature descriptors to automate the placement of markers. They usually require a large database of 3D scans. We propose to automatically estimate the body pose of a person from a 3D mesh acquired by standard 3D body scanners, with or without texture. To fit a human model to the scan, we use joint locations as anchors. These are detected from multiple 2D views using a conventional body joint detector working on images. In contrast to existing approaches, the proposed method is fully automatic, and takes advantage of the robustness of state-of-art 2D joint detectors. The proposed approach is validated on scans of people in different poses wearing garments of various thicknesses and on scans of one person in multiple poses with known ground truth wearing close-fitting clothing.

A Model-based Approach to Rapid Estimation of Body Shape and Postures Using Low-Cost Depth Cameras
Byoung-Keon D. PARK, Matthew P. REED
University of Michigan, Transportation Research Institute, Ann Arbor MI, USA
Depth cameras have revolutionized anthropometry providing efficient ways to gather 3-dimensional information of a human body in varied settings. However, the accuracy and resolution of the current depth camera systems limits their applicability for many applications. Commercial markerless motion-capture systems based on depth camera technology are similarly limited, particularly by the lack of a model-based tracking mechanism and a high dependence on unobstructed camera views. This paper presents a series of model-based methods for

estimating body configuration and postures based on depth and posture data obtained from a single Kinect v2 sensor. The software system records and processes multiple depth images of a person from different point of views to capture the whole-body shape. A statistical body shape model that can represent a wide variety of human body shapes and poses was generated by analyzing template-fit whole-body laser scans and measured anatomical landmark data using a principal component analysis (PCA). PCA reduces the high dimensionality of the original data source by projecting the dataset to a low dimensional principal component (PC) space. In the PC space, only realistic body shapes and landmark data can be generated, and this space allows for efficient body shape search due to the low dimensionality. Using this model, a rapid fitting method for generating a subject-specific manikin from Kinect depth data was developed that can estimate a minimally-clad body shape under normally clothing. Posture data from subsequent movements estimated by the built-in skeleton tracker in the Kinect system were further improved by fitting each body segment of the manikin to a corresponding partial depth dataset while the segment lengths were preserved as defined in the manikin. This study demonstrated how a model-based approach can improve the accuracy and feasibility of a depth camera system so that the system can be readily applied for various applications, including in-vehicle occupant dynamic analysis, occupant classification, and markerless motion analysis.

Shape Customisation of Human Subjects Based on Human Parsing Technology
Shuaiyin ZHU, Yanghong ZHOU, P.Y. MOK
Institute of Textiles and Clothing, The Hong Kong Polytechnic University, Hunghom, Hong Kong
Human modelling is an active research topic in medical, fitness and entertainment (such as game and movie) related studies. Many methods have been reported in the literature for human modeling, wjocj can be classified as scan-based, image-based and example-based approaches and all have pros and cons. In this paper, we propose a complete automatic method for human model shape customization based on the cutting-edge human parsing technology. The method allow users efficiently customize human models using orthogonal-view images in a complete automatic pipeline. We have demonstrated that our automatic customisation method is robust that generates accurate digital models for individuals using two images, and the method applies to male and female subjects, in tight-fit or arbitrary (normal and/or loose-fit) clothing, with different background conditions of the input images. Experimental results have demonstrated that our method improves accuracy, robustness, efficiency, and flexibility of human shape modelling.

TECHNICAL SESSION 12: 3D TECHNOLOGIES FOR APPAREL II

The Digital (R)evolution - Solutions to Drive through Tumults Times
Sabrina COVE
EFI Optitex, New York NY, USA
Retail world is changing, forever so it seems. With numerous store closing and changes in how consumers shop, brands and retailers must also consider new ways to develop as they work to change how quick they develop and deliver to consumers' homes and the stores, while maintaining margins and relationships with their supply chain. In this session we will discuss and review how brands and retailers are changing, how they develop sooner and more accurately to our taste, how they reach us faster and with less errors. Technology has drastically evolved in its offering for PD, and all the way to how the item is delivered to the end user. Join this session to Understand the Technology of Things.

Slow Adoption of Technology in the Apparel Manufacturing Industry’s Implementation of Mass Customization
Jocelyn BELLEMARE
University of Quebec in Montreal (UQAM), Dept. of Management & Techn. Management, Montreal QC, Canada
This paper outlines and discusses the possible causes of the slow adoption of technology for mass customization in the apparel and fashion industry. The study first identifies (based on a number of interviews with apparel producers) the performance indicators and the integration of technologies necessary for the implementation of a system of mass customization in the garment industry. The interviews with these producers reveal certain factors and characteristics that can explain this slow adoption. Our research looks into the factors and industry characteristics in large part explaining the apparel industry’s difficulties and lateness in implementing one of the most important recent innovations: the mass customization of garment products. We

argue that one of the major difficulties arises from the lack of integration between the technologies presently used by the industry and those offered by the providers of new systems. The products offered do not meet the apparel manufacturers' and distributors' needs and expectations. Our interviews with different stakeholders point to: (1) a lack of technological fluency on the part of both managers and labour, (2) a strong resistance to change in a very traditional industry that still relies on outdated work habits, (3) a lack of proactivity and implementation of strategic or technical watches, (4) minimal investment due in part to the difficulties of borrowing money, and (5) the bad press often given to technology and mass customization implementations by certain important industry actors. Past research has demonstrated the importance of understanding the mass customization of garment within the context of trade globalization and the industry 4.0, which has led to ever more fierce competition in the global fashion and apparel market. But, why is the manufacturing industry so late in understanding this? According to your results, the principal cause is the lack of integration between technologies currently in place and those offered by suppliers which do not adequately respond to the needs of manufacturers and distributers.

3D Body Scanning has Suitable Reliability: An Anthropometric Investigation for Garment Construction
Christopher J. PARKER, Simeon GILL, Steven G. HAYES
The University of Manchester, Manchester, UK
3D Body Scanning provides access to a greater breadth and depth of anthropometric data for industry applications and scientific research than at any other point in history. However, while the potential of this technology for revolutionising industrial and scientific practices has been established, little exists addressing its appropriateness in terms of reliability within recognised allowable error. To address this issue, this study investigates the degree to which 3D Body Scanning can produce reliable anthropometric measurements for use in garment construction and scientific research. 27 participants were repeatedly scanned using a SizeStream Body Scanner five consecutive times to find out the variation in reliability between instances of data capture. The variance to three Standard Deviations was then compared to established allowable error guidelines to assess suitability of the measurements attained. The main outcome of this study is that 3D Body Scanning can achieve suitable reliability to be used in garment construction, tailoring, and scientific research; providing 99.73% confidence in the suitability of extracted dimensions in 49% of the most commonly used body measurements. However, other measurements achieved less exceptional reliability, and therefore use of traditional measurement methods need to be considered carefully when generating tailored garments or comparing anthropometric data sets from 3D Body Scanners. As a consequence of this study, 3D Body Scanning shows suitable reliability for most garment construction and anthropometric research tasks.

Panel - Discussion - Retail & 3D Tech: Bridging the Gap
Stephen CROSSLAND1, Joe DIXON2, Mark PISZCOR3, Sabrina COVE4, Elizabeth STEFANKA5
1 Point Vision LLC, Pittsburgh PA, USA;
2 Size Stream LLC, Cary NC, USA;
3 Occipital Inc., San Francisco CA, USA;
4 EFI Optitex, New York NY, USA;
5 STEFANKA, Montreal QC, Canada
Retail is changing and is in urge to integrate innovative experiences. A new era of 3D technology and processes is emerging, thus retailers seek to integrate solutions for their consumers who are expecting a more personalized and unique experience. This panel will discuss about the latest technologies to be brought in the stores. Moreover, the challenges to implement efficient relation with retailers and the final consumers.

TECHNICAL SESSION 13: SCANNING METHODS & TECHNOLOGIES

Deep Learning based Aesthetic Evaluation of State-Of-The-Art 3D Reconstruction Techniques
Gernot STUEBL, Christoph HEINDL, Harald BAUER, Andreas PICHLER
PROFACTOR GmbH, Steyr-Gleink, Austria
In the field of 3D human body scanning, due to different scanning technologies different reconstruction approaches have emerged. The two main ones are based either on pure 2D information, like photogrammetry, or 2D plus depth, as used with RGBD active structured light sensors.
Reconstruction results of these technologies differ in geometric as well as aesthetic quality. Whereas the

judgement of geometric quality is straight forward, a judgement of the aesthetics aspects (e.g. proper texture mapping, etc.) strongly depends on the subjective perception of the human viewer.
Recent advances in image aesthetics assessment, demonstrate that machine-learning algorithms, specifically deep neural networks, are able to model human aesthetic perception in a reasonable way. Especially if they are trained with a huge number of data.
This work presents research towards an unbiased aesthetic judgement of 3D reconstructions by utilizing a deep neural network. In detail, two state-of-the-art software suites as representatives for 2D and 2D plus depth reconstruction approaches are compared according to the aesthetics of their results. The models of a publicly available dataset are virtually scanned with a sensor simulator, which produces the necessary 2D and depth information. This data serves as input to the mentioned software suites. The resulting 3D reconstructions are aligned and a deep neural net aesthetically compares frontal views of the models. To ensure a fair comparison between different models a normalized aesthetic value is introduced.

Design and Development of a Rotary 3D Scanner for Human Body Scanning
Khalil KHALILI, Mojtaba ZERAATKAR
Mechanical Engineering, University of Birjand, Birjand, Iran
In recent years, reverse engineering industry has experienced remarkable overhaul owing to the advancements in electronic and optic industries. 3D scan technology finds new applications ranging from industrial to common everyday subjects. One of its applications is in the field of 3D scanning of human body. Human scanning is of complicated items for modeling due to non-rigidity and large time interval required for entire body measurement. Human scanning has different applications in the fields of sculpturing, medicine, sports, clothing and security. There are limited number of commercial scanners in the field of human body scanning and are generally categorized into two groups depending on the utilization of laser technology or image for extracting the geometric parameters. A variety of companies offer laser systems, although they are often costly. With regard to human scanning, it must be noted that some scanners may be hazardous or dangerous for human due to their special lighting (such as laser). Plus, individuals mentally prefer not to be exposed to laser radiation. Hence, image-based scanners are more acceptable for human scanning. This paper presents the design and manufacture of a rotary 3D scanner for human scanning which employs the structure from motion method to extract 3D data from the object. The system employs typical inexpensive camera and lighting source, as a result of which the system is very low cost. The design process to create a 3D scanning system that is presented in this paper may be categorized into three general sections. First section includes the design and creation of physical structure of the system, second section includes the electronic components of system, and the third section is the system software. The scanner uses 2D images to extract the 3D model. For image capturing and their quick transmission to the server, relevant camera and boards were utilized. The boards together with the cameras should be mounted in certain positions relative to the object, and they should have 360° of rotary freedom to be capable of capturing images from the object. The design and production process has been carried out in the University of Birjand.

Multi-Projector Multi-Camera Structured Light 3D Body Scanner
Tomislav PETKOVIĆ1, Tomislav PRIBANIĆ1, Matea ĐONLIĆ1, Nicola D'APUZZO2
1 University of Zagreb, Faculty of Electrical Engineering and Computing, Zagreb, Croatia;
2 Hometrica Consulting, Ascona, Switzerland
Human body scanners using structured light are usually comprised of one projector which provides a limited view of the body surface due to limited field-of-view. To scan the whole surface of a human body multiple projectors must be used. Using more than one projector in a structured light scanner is typically difficult due to inter-projector interferences which make surface reconstruction a hard task. We propose to use temporal phase-shifts to enable multiplexing in fringe-projection profilometry. In our approach each projector projects a sinusoidal fringe pattern having its own specifically chosen set of temporal phase shifts so for a system of P projectors all temporal phase shifts together comprise a DFT_{2P+1} basis. Such choice of temporal phase shifts enables simple and efficient separation of the combined pattern into the contributions of each projector. The proposed approach places no constraints on the number of projectors and on spatial projector placement. We demonstrate the applicability of the proposed approach on a prototype human body scanner using three projectors and six cameras.

High Speed Measurement for Handheld 3D Imaging System Based on Triple Epipolar Constraint

Qijian TANG1, Xiaoli LIU1, Yang YANG1, Chang LIU1, Menglong LIU2, Kaibing XIANG2, Xiang PENG1,2
1 Key Laboratory of Optoelectronic Devices and Systems of Ministry of Education and Guangdong Province, College of Optoelectronic Engineering, Shenzhen University, Shenzhen Guangdong, China;
2 Shenzhen ESUN Co. Ltd., Shenzhen Guangdong, China

Handheld 3D imaging system has been widely used in areas of industry, medicine and aerospace, due to its good performances such as: noncontact, high flexibility, portability and high efficiency. It is often consisted of a stereo vision system, and realizes 3D reconstruction by projecting random or coded patterns to find point correspondences to calculate 3D space coordinates. Among optical 3D measurement techniques, fringe projection profilometry (FPP) has become one of the most popular techniques as a result of its simple system structure, high precision, full-field scanning, and automatic processing. However, FPP is rarely used in handheld 3D systems, the reason is that FPP has to project many patterns to acquire 3D information, which is not suitable for handheld condition, especially hand shaking will introduce huge error into depth measurement result. To overcome this, higher projecting speed and lower image counts for single view 3D measurement become hence necessary. In this paper, we propose to reduce the image counts by employing triple epipolar constraint, where the projector is treated as a camera, as shown in figure 1. As a result, with triple epipolar constraint, correspondences can be found without phase unwrapping. For N-step (N>=3) phase shifting method, the system only projects N patterns. The projector speed is 120 frames/s, take N=3 as an example, the reconstruction speed can reach 40 frames/s. With image multiplexing, as shown in figure 2, the reconstruction speed reaches projecting speed. In hence, the paper realizes high speed measurement for handheld 3D imaging system with FPP.

TECHNICAL SESSION 14: 3D BODY PROCESSING

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

Carol MCDONALD1, Luciano OVIEDO2, Alfredo BALLESTER3
1 Gneiss Concept, Woodinville WA, USA;
2 Intel, Santa Clara CA, USA;
3 Instituto de Biomecánica, Universitat Politècnica de València, Valencia, Spain

The IEEE 3D Body Processing (3DBP) initiative is working towards standardizing 3d body technologies by creating use cases, identifying gaps in standards and identifying best practices for 3D body processing. The 3DBP brings together an ecosystem of players to propose new standards around enabling 3D body processing for a variety of use cases. Companies include large retailers, scanner providers, virtual fit providers, and small to mid-sized start-ups. The range of body processing use cases involves apparel, footwear and accessories, such as eyewear and gloves. Body processing encompasses the capture, processing, storage, and sharing – all of which relies on “Of-the-body” landmarks and “On-the-body” models.

The committee is making progress on recommending file formats, metadata and communication protocols for global file sharing and interoperability. Thus far, the committee primarily focuses on the retail use case, especially with regard to fit and size estimation, product recommendations and improved sizing systems. For clothing manufacturers and CAD tool developers, the main use cases are: bespoke or custom manufacturing, and bi-directional transformations between 2D patterns and 3D models.

Technical work groups intend to improve interoperability between creators and consumers of 3D body models and accelerate the implementation of body model centric use cases. The first step is to identify gaps in existing standards and recommended practices as 3D body processing spreads beyond first adopters. Separate interoperability work groups are dedicated to metadata, file format, protocol, security and model accuracy estimation.

The metadata technical group intends to define mandatory and optional metadata, recommend landmark and measurement names and definitions (based on existing standards), and allow for vendor-specific metadata. The file format technical group intends to select between existing file formats that support model 3D data, such that all metadata defined earlier is contained within the same file. The protocol and security technical group intends to select an existing protocol that will allow for the request and sending of the body model, using generic APIs, while providing security.

The model accuracy technical group intends to create a ground truth database for assessing the accuracy of software packages with landmark placement and measurement values. The definitions for landmarks and

measurements (L&M) are defined using the latest versions of various ISO standards.
The raw data from the body scanners themselves are out of scope. However, the type and make of the scanner must be stated in the metadata for reference. The software will be evaluated after the 3D body model and the statistical models have been generated and compared to the L&M ground truth for accuracy.

Statistical Learning of Human Body through Feature Wireframe

Jida HUANG1, Tsz-Ho KWOK2, Chi ZHOU1
1 Industrial and Systems Engineering, University at Buffalo, SUNY, Buffalo NY, USA;
2 Mechanical, Industrial and Aerospace Engineering, Concordia University, Montreal QC, Canada

Statistical learning of human body shape can be used for reconstructing/estimating body shapes from incomplete data, semantic parametric design, modifying images or videos, or simulation. It is applicable in many areas including computer vision & graphics, ergonomic design, personalized design, or virtual try-on. A digital human body is normally represented in a high-dimensional space, and the number of vertices in a mesh is far larger than the number of human bodies in publicly available databases, which results in a model learnt by Principle Component Analysis (PCA) can hardly reflect the true variety in human body shapes. Furthermore, if the number of vertices and size of database are large, it will be very challenging to perform PCA on such a huge problem. This paper presents a hierarchical method for statistical learning of human body by using feature wireframe as one of the layers to separate the whole problem into smaller and more solvable sub-problems. The feature wireframe is a collection of feature curves which are semantically defined on the mesh of human body, and it is consistent to all human bodies. A set of patches can then be generated by clustering the whole mesh surface to separated ones that interpolate the feature wireframe. Since the surface is separated into patches, PCA only needs to be conducted on each patch but not on the whole surface. The spatial relationship between the patches and the wireframe are learnt by linear regression. An application of semantic parametric design is used to demonstrate the capability of the method, where the semantic parameters are linked to the feature wireframe instead of the mesh directly. Under this hierarchy, the feature wireframe acts like an agent between semantic parameters and the mesh, and also contains semantic meaning by itself. The proposed method of learning human body statistically with the help of feature wireframe is scalable and has a better quality.

Body Type Classification of the Three-Dimensional Torso Shape of Japanese Men Aged 20 to 70 Years for Efficient Clothing Design

Keiko WATANABE
Kyoto Women's University, Kyoto, Japan

In Japan, the men's clothing industry has faced repeated price competition. However, it seems that price competition is also reaching its limit. Consumers are looking for new added value, and clothes that fit the body by a new made-to-measure system could be one solution. An appropriate classification system of body types is needed for an efficient made-to-measure system. However, analysis of male bodies has rarely been performed in Japan. The final purposes are to classify the body types among Japanese men, and create a new made-to-measure system using three-dimensional body scanning data. In this study, our aims were to clarify factors that account for the diversity among Japanese men's body shapes, and to develop a classification system for Japanese men's body shapes. The data of 50 men in each age group of men in their 20s, 30s, 40s, and 50s and 50 men in their 60s and 70s, totaling 250 men, were randomly selected from 429 men aged 20 to 79 years old. A body line scanner was used to measure each person's body. In this study, the trunk, which was restricted to the inside of the arm hole, below the neckline, and above the trochanter point, was analyzed. The origin was unified based on the landmarks: the back-neck point was the origin of the X-axis (transverse direction), the trochanter point was the origin of the Y-axis (vertical direction) and the right-side neck point was the origin of the Z-axis (sagittal direction). To enable statistical analysis, the data from each individual were transformed to a homologous model by HBM software. The homologous models were analyzed by principal component analysis with DHRC-HBS Human Body Shape Statistics software. Seven factors were extracted and interpreted as follows. The first principal component (PC1) was the factor of height of the trunk. PC2 was inclination of the torso forward or backward above the waistline. PC3 was thickness of the torso. PC4 and PC5 were left / right difference. PC6 was forward or backward shoulder. PC7 was considered as distortion of the shoulder relative to the lower trunk. The principal component scores for PC1, PC2, PC3, and PC6 were used in cluster analysis with the statistics software IBM SPSS Statistics. The analysis resulted in seven clusters. CL1 and CL4 were similar to the average shape of the 250 subjects, although CL4 was taller than CL1. CL1 and CL4 accounted for 50% of the men in the groups of men in their 30s, 40s, and 50s. CL6 was slenderer than CL1; in CL6, the body trunk

was thin and showed swayback, and its frequency was relatively high among men in their 20s. CL7 represented good posture with a developed chest. CL3 had a round back and front shoulder and these men were short; CL3 comprised 50% or more of the men in their 60s and 70s. CL2 was bending backward with a protruded stomach, which is considered to be the so-called metabolism type, and comprised 20% of men in their 50s. This body classification system is considered to be applicable for virtual dress dummy design and for a made-to-measure system.

Cloud Services for Processing 3D Full Body Scans

Yannick FRANCKEN, Stijn LIGOT
3D Body Cloud, Antwerpen, Belgium

We present a cloud solution for automated processing of 3D full body scans. Manually processing 3D full body scans into producible or publishable products requires specialized knowledge, expensive software and a considerable amount of time. By automating these tasks and offering them as a scalable cloud service, the processing time as well as financial cost decreases tremendously. This means that in the same time span, a higher number of scans can be processed. Due to the increasing number of 3D full body scanners in the market and the quantity of scans they can produce per unit of time, we believe fast processing has become a necessity.
Our approach allows for offering scan to product conversion by a single API call, while being able to deal with different types scan data, product definitions and special requirements. We achieve this by building easily configurable modules and combine them into suitable pipelines for every specific situation. Modules are for example hollowing, fixing or thickening of meshes, automated rigging and skinning, creating 2.5D bas-reliefs, texture unwrapping, color corrections, rendering and many more.
Final products, and hence available API calls, are for example branded videos of animated scans in a virtual world, digital 3D printable figurines standing on a personalized baseplate, a physically produced 2.5D smart-phone cover etc. Depending on the processing software of each module, certain hardware solutions are wishful or even required. In order to limit wasted computational power, we have opted for a flexible light-weight distributed processing approach. Each processing entity picks up tasks that are suited for the hardware it is running on. Processing entities are spread over commercially available cloud processing solutions and on premise single-board computers as well as servers with GPU power.
In the near future we will allow third parties to add new modules and let them monetize their efforts via the scan traffic we have. This will not only be technically challenging, but also from a privacy point of view to make sure we keep on being compliant with the General Data Protection Regulation.

Published by
Hometrica Consulting - Dr. Nicola D'Apuzzo
Via Collegio 28, CH-6612 Ascona, Switzerland
+41 91 7915524 info@hometrica.ch www.hometrica.ch