13th 3DBODY.TECH Conference & Expo
Lugano, Switzerland · 25-26 October 2022
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Book of Abstracts

3DBODY.TECH 2022

13th International Conference and Exhibition on

3D Body Scanning and Processing Technologies

Lugano, Switzerland, 25-26 October 2022

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Editor and Organizer

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

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OPENING SESSION

3DBODY.TECH 2022 - Introduction 00

Nicola D'APUZZO

Hometrica Consulting, Ascona, Switzerland

3DBODY.TECH 2022 - The 13th International Conference and Exhibition on 3D Body Scanning and Processing Technologies took place on 25-26 October 2022, in Lugano, Switzerland.

3DBODY.TECH 2022 was held as hybrid onsite+online event with conference and exhibition taking place simultaneously onsite at the Lugano convention center and live-streamed on the online conference platform. In-person onsite and/or remote online participation was possible for attendees, speakers, exhibitors.

This event was organized by Hometrica Consulting - Dr. Nicola D'Apuzzo, Switzerland.

3DBODY.TECH Conference & Expo, the premier multidisciplinary international conference and exhibition on 3D human body scanning and processing technologies, provides a platform of eminent professionals, entrepreneurs, academicians and researchers across the globe to present, learn and discuss the latest in 3D human body scanning and processing technologies.

The multidisciplinary character of 3DBODY.TECH makes it unique and not comparable to any other meeting related to 3D body technologies.

3DBODY.TECH Conference & Expo website 3dbody.tech gives all information related to this event.

The contents of the presented works at the conference are related, but not limited to, the following technical areas:

- 3D & 4D body and 3D & 4D face scanning methods, systems and technologies
- 3D body processing methods and technologies, 3D & 4D scan data processing
- 3D body modeling, 3D body visualization, 3D body printing methods and technologies
- 3D digital humans, virtual humans, avatars, metaverse
- Active and passive 3D scanning technologies for the human body (full body, bust, face, feet, etc.)
- 4D scanning, volumetric capture and MOCAP technologies for the human body
- Mobile/portable and hand-held human body scanning and measurement systems, devices, solutions
- Machine learning and artificial intelligence for 3D body scanning and processing
- Full body scanning and measurement systems for the apparel and fashion sector
- 3D virtual fitting, 3D digital fashion, 3D cloth simulation, virtual mirrors
- Applications in medical sciences (plastic surgery, orthotics, prosthetics, forensics, etc.)
- Foot scanning and measurement systems for footwear, sport and orthopedics
- Digital anthropometry, anthropometric studies, ergonomics
- Body measurement and sizing campaigns, fitting mannequins
- Biometrics and applications in security
- Applications in sport, health and fitness
- Applications in virtual life, games, FX and entertainment
- Applications in social sciences, and communication

These proceedings gather the papers presented during the conference by renowned experts in the field of 3D body scanning and processing. The technical papers are organized in theme sessions.

The website 3dbody.tech/cap is dedicated to the proceedings of the serie of conferences and workshops on 3D Body Scanning & Processing Technologies and their contents.

The abstracts and papers of over 500 publications included in the proceedings of all conferences and workshops are available at the website and accessible from its different sections. The full papers are available for download as single documents (PDF), the entire proceedings in digital form (html structure and PDF files) are available for purchase. The videos of the single presentations are also included when available.

TECHNICAL SESSION 1: 3D/4D Body Scanning & Processing

3D Scanning Technologies for Human Face Expression Recognition: A Comparison Framework 71

Luca ULRICH, Sandro MOOS, Federica MARCOLIN, Enrico VEZZETTI

Department of Management and Production Engineering, Politecnico di Torino, Turin, Italy

In the last few years, application fields for face analysis have considerably increased, phenomenon that has been fed by a significant improvement of acquisition technologies. In this work, the focus is

pointed on face expression recognition, which aims to recognize user's feelings through the analysis of facial data for different applications that moves from security to marketing domain. Data considered in this research are those acquired from 3D cameras that seem to provide more reliable performances rather than 2D devices, especially in “nonstandard” working conditions. This study aims to create a framework able to support a systematic analysis and comparison of 3D acquisition technologies to support the development of real-time applications, with a specific focus on RGB-D.

Personalized Fitting of Respiratory Mask Using 3D Numerical Simulation and Finite Element Analysis 48

Hugo TAECKENS 1, Arthur AGOSTINI 1, Loic DEGUELDRE 2, Bahe HACHEM 2, Sean-Philippe VIENS 3, Aude CASTONGUAY-HENRI 3, Jonathan BORDUAS 3, Luc DUONG 1

1 Ecole de Technologie Superieure, Montreal (QC), Canada;
2 Numalogics, Montreal (QC), Canada;
3 ShapeShift 3D, Montreal (QC), Canada

Respiratory masks, such as N95, are widely used in clinical and industrial environments because of their high filtration capacity. However, prolonged wear could provide discomfort due to poor fitting to each individual's face's exact morphology and excessive tightening.

This study aims to personalize the design of respiratory masks and simulate the fitting using finite element analysis. A cohort of 7 participants was recruited to evaluate the fit of a virtual 3D mask. A scan of the face was performed on an iPhone by an app using ARKit to acquire a geometric model for simulation.

The mask pressure and seal were calculated digitally using Ansys Mechanical after importing the 3D geometries of the mask and the face. An algorithm allows to place the mask in front of the face without inter-penetration. Facial soft tissues were accounted as a homogeneous hyperelastic material model. The silicone was modeled using hyperelastic material properties and the mask was considered as rigid. A pressure map illustrates the pattern that the mask will produce on a given user's face, in order to assert the desired comfort criteria. A map of the gap between the mask and the face shows the sealing capability of the mask. The pressure points of the silicone on the face were simulated after tightening the mask. The pressure pattern must be uniform and without pressure peaks to ensure user comfort.

To ensure the consistency of the numerical results, experimental pressure measurements were also performed on the participants and their dedicated masks. Facial pressure calculation and measurement tests were performed under 3 levels of tightening (low = 5N, medium = 13N and high = 20N).

The outcome of this study could provide major insights in the design of respiratory masks through face scanning technologies and numerical simulation. Moreover, it could contribute to fully customize the respiratory mask to the user's face, for enhanced comfort and proper sealing.

Opportunities and Current Obstacles to Use MOVE4D for Cycling Analysis 42

Alexander VAN GASTEL, Stijn VERWULGEN

University of Antwerp, Antwerp, Belgium

In this white paper, the opportunities and current obstacles to use the Move 4D markerless motion tracking system (Instituto de Biomecanica de Valencia - IBV), for capturing human product interactions is discussed. In particular, this whitepaper focuses on scanning cyclists to map and improve biomechanical efficiency and aerodynamics. If successful, it could lay the technological foundation to extend current CFD (computational fluid dynamics) analyses, with flow simulations executed with a dynamically moving body and bicycle based on a high resolution and high framerate 4D mesh. Furthermore, the homologous mesh export function could allow bike fitters to use digitally standardized measurement points for biomechanical assessments. In contrast, marker-based motion tracking systems require hand placement of markers that are susceptible to faults such as placement position errors, low battery while recording, and falling off the skin. A markerless system could also improve flexibility for researchers to find new relevant measurement points due to the flexibility of digital markers. Current obstacles are revealed during an exploratory observation: 1) recording a professional time trail rider. A primary obstacle in capturing human product interactions is that the system does not provide a usable homologous mesh, due to the system's inability to separate the object, in this case, the bicycle, from the cyclist. Two follow-up observations explore the effect of coating objects, used in human-product interactions, with material that do not emit infrared (IR) in broadbands of 3–5 μm and 8–14 μm: 2) exploring coatings that avoid detection by IR cameras, and 3) recording a human product interaction with an object coated in a material that avoids detection by IR cameras. Results shows that

these coatings on objects used in a human product interaction enables the system to capture the actor's full dynamic movement, without the object being captured. This way a dynamically moving, watertight, and accurate homologous 4D mesh can be created of the actor.

OrienNormNet: Orientation Normalization of 3D Body Models 36

Ran ZHAO, Xinxin DAI, Pengpeng HU, Adrian MUNTEANU

Vrije Universiteit Brussel, Brussels, Belgium

3D human body models are widely used in human-centric industrial applications, including healthcare, fashion design, body biometrics extraction, and computer animation. Prior to processing and analyzing body models, it is significantly important to rotate them to the same orientation. For instance, body measurement systems and virtual try-on systems usually assume the orientation of the body is known. These systems will output incorrect results or report errors without the correct orientation information. Unfortunately, the orientations of scanned bodies are different in practice since they are in different coordinate systems due to the setup variations of scanners. To automatically normalize the orientations of bodies is a challenging task due to the presence of pose variations, noises, and holes during 3D body scanning. In this study, we propose a novel deep learning-based method dubbed OrienNormNet for normalizing the orientation of 3D body models. As shown in Figure 1 and Figure 2, OrienNormNet directly consumes raw point clouds or mesh vertices, and it is applied in an iterative manner. First, the centroids of point clouds are translated to the origin to obtain zero-centered point clouds. Next, OrienNormNet consumes zero-centered raw point clouds and outputs coarse axis rotation angles. Finally, OrienNormNet takes the coarsely rotated point clouds from the previous processing as an updated input and outputs the refined axis rotation angles. By applying the obtained coarse and fine axis rotation angles, thousands of bodies can be adjusted to the same orientation in a few seconds. Experimental results based on synthetic datasets as well as real-world datasets validated the effectiveness of our idea.

Adaptive Body Circumference Measurement Technique using Ellipse Formula 12

Mohammad MONTAZERIAN, Frederic FOL LEYMARIE

Goldsmiths, University of London, Computing Dept., London, UK

In the present paper, ellipse-like approximations are considered with the aim of minimizing the difference between the results of direct and software measurements. The human body can only be approximately represented by elliptic cross sections, and these can vary for each individual. We show that better results are obtained by adapting the fit to the body shape based on a simple criterion. Based on this study, we have selected two mathematical models to estimate upper human body circumferences.

The result is a fully trained system that can choose the best ellipse equation according to the human body shape to calculate human body circumferences.

TECHNICAL SESSION 2: 3D/4D Body Scanning Systems and Uses I

Yes, We Scan 53

Beatriz MAÑAS BALLESTER

IBV Instituto de Biomecanica de Valencia, Universitat Politecnica de Valencia, Spain

Dynamic analytics of the human body are undergoing drastic changes with the progress of technologies based on anthropometric data and artificial intelligence (AI). At the Instituto de Biomecánica (IBV), we have an advanced environment to study and attain greater knowledge about human interactions: our Human Analysis Lab (HAL) uses the Move4D system, a new generation scanner that captures the body shape in motion at high speed and resolution. This technology opens up a world of new and exciting opportunities in fields such as Biomechanics, Apparel, Computer Vision or the Metaverse.

Our presentation will cover the overview of the Institute, the key features of the Move4D scanning system and the ongoing developments with representative cases of improvements of aspect, improvements of algorithms, dynamic measurements and the integration into different pipelines.

Commercial and Research Revolutions Enabled by 3D Body Scanning 01

David BRUNER, Richard ALLEN

Size Stream LLC, Cary NC, USA

Applications ranging from sizing surveys, made-to-measure apparel, uniform and apparel sizing, health, and fitness have used 3D body scanning over the past thirty years to provide accurate human body measurements, shape characterization, and commercial development. There has been significant progress in developing data processing for these applications. Three main widespread roadblocks these solutions are experiencing includes: High cost of 3D body scanners in terms of capital and space; Limited access to 3D scanning by end consumers; Concerns about data privacy.

In our presentation we will cover how Size Stream has been able to remove these roadblocks by developing and deploying the ability to 3D body scan with the use of the technology embedded in today's smart phones and tablets. Real world applications in the apparel and health & fitness spaces in total approach million-user audiences, validating the viability and effectiveness of 3D body scanning for the future in research and commercial aspects not available.

Size Recommendations and their Opportunities for the Workwear Sector 08

Minou LASHGARI, Ulrike GRUEN

Avalution GmbH, Kaiserslautern, Germany

Avalution is specialized in scanning, measuring, analyzing, and digitizing real people. Based on the huge database of 3D data and body measurements from almost all over the world, Avalution offers solutions around 3D body scanning, avatars, size recommendations and size chart optimization for customers from the automotive and the fashion & apparel market, but also for consumer electronics, leisure & sports and healthcare & medical applications.

Suppliers in the workwear sector currently face many challenges. Sector diversity, a large number of different products with different materials, different suppliers and thus different sizing systems require a lot of time and specialized staff, but is also a necessity for providing the right sizes for their products to the actual wearer.

So far, a sales representative of the workwear company drives, with clothes in the trunk of his car, to a fitting process on site. However, the bigger the customer, the more it comes down to a size query based on the wearer's wearing habits and thus to ordering and delivery based on size assumptions. This in turn can lead to increased returns and re-ordering of other sizes. All in all, this is associated with further efforts and costs and often leads to customer frustration.

Today, the time-consuming travel of sales representatives can be dispensed with. Before any size recommendation is made, body measurements must be taken by a scanner, either the AVAone or the virtual scanner.

The 3D body scanner AVAone uses the measuring principle of depth sensor technology. It provides 50 body measurements that can be used within the size recommendation. The Virtual Scanner is a user-friendly software tool with the only need of an internet connection and a computer. The Avalution database with 3D measurements from representative size surveys is used to calculate the statistical avatar. This solution also eliminates the need for the wearer to undress down to their underwear. The virtual scanner stands out due to its simple handling. The user is guided successively through a few questions on gender, body height, weight, age and body shapes. Based on this information an associated avatar and body measurements are determined.

The size recommendation is based on the previously mentioned body measurements and the size tables of the individual products with body measurements and/or garment measurements and ease information. Product and brand relevant measurements are taken into account.

Experience shows that products with many size runs or individual wearing behavior influences the process of the first size recommendation. In addition, the product information often does not correspond to the actual behavior of the garment. Based on years of experience, the size recommendations are continuously optimized in the ongoing process. Our customizable platform offers an infrastructure for uploading product data and setting up web service size recommendation with flexible connection to body scanner and virtual scanner.

It has been proven in different customer projects that the technically supported size recommendation leads to significant process simplifications and savings and is especially able to provide the best fitting sizes for the individual wearers. The frontend (scanner or virtual scanner) may be selected with respect to the number of wearers at one location, so that the workwear company has the greatest flexibility.

TECHNICAL SESSION 3: 3D/4D Body Scanning Systems and Uses II

Mantis Vision Volumetric Capture Studios and Use Cases 74

Rob CHRISTENSEN
Mantis Vision USA, Rapid City SD, USA

Abstract not available.

TECHNICAL SESSION 4: 3D/4D Body Scanning for Apparel I

Development of Clothing-Related Assistance Systems to Support the Mobility 09

Ellen WENDT, Doudou ZHANG, Sybille KRZYWINSKI, Yordan KYOSEV
TU Dresden, Institute of Textile Machinery and High Performance Material Technology, Germany

The aim of this research is the development of a clothing assistance system to support the mobility of older people, especially the movement from sitting to standing. The solution adapts to the body proportions, postures and movements that change with age without reducing the body's own strength and counteracting muscle degeneration. The energy storage and release required for support is realised by textile materials with different levels of strain stiffness. A wide range of elastic drawstrings is available for this purpose. Their integration into the overall system of the functional clothing in terms of production technology is intended to provide proportional support for muscle strength on the one hand and ensures good wearing comfort on the other. The result of the development is a passive exosuit in the form of functional underwear that can be worn under daywear.

Testing a Smartphone Application for the Optimisation of Organisational Outfitting Procedures for Protective Clothing 07

Dominik OEHLSCHLAEGER 1, Marina WEISSE 2, Cindy BAGGE 2, Carsten ZIMMERMANN 2, Andreas H. GLAS 1, Jens HOLTMANNSPOETTER 2, Michael ESSIG 1
1 Bundeswehr University Munich, Neubiberg, Germany;
2 Bundeswehr Research Institute for Materials, Fuels and Lubricants, Erding, Germany

Allocating protective clothing to personnel of emergency service organisations requires a substantial amount of time and effort. This makes these processes costly and laborious. Data-driven outfitting bears the potential to increase efficiency both economically and ecologically. Therefore, this study explores a smartphone application’s feasibility to enable virtual human-product matchmaking within the context of organisational outfitting procedures. This is achieved by testing the application’s ability to capture individual body data of users and associate these with product dimensions.

The application’s performance is evaluated by contrasting the accuracy of its results with those of a laser-based 3D body scanner as well as through physical inspection of results. For this purpose, an experiment has been conducted in which 63 members of the German Armed Forces were given the task to scan themselves via a smartphone application. Obtained information was transferred to a mock-up online shop where a pretrained algorithm automatically matched various body dimensions to the optimal sizes of ten different clothing products. Thereafter, participants were given the selected products for physical trial fitting. The fit of each solitary product and the products' combinability were subjectively evaluated by the participants and objectively by a clothing technician and a tailor.

Findings show that the smartphone application is feasible to enable the outfitting procedure's digitisation, although body data captured by the smartphone application was of lower accuracy than data gathered by the laser-based 3D body scanner. Furthermore, the experiment's findings helped to uncover issues of incumbent product dimensions and size ranges as well as substantiated the importance of gender-specific clothing since the usage of unisex products led to poor results for the female subpopulation. For the male subpopulation, 86 per cent of products were optimally allocated, the wrong size was chosen in 12 per cent of cases, and in two per cent of cases the system failed to select any product at all. By analysing these aspects, the findings shed more light on technical issues such as measuring errors or flaws of the allocation algorithm.

The study evinces current potentials and troubles of both the smartphone application and the digital outfitting system which offer avenues for future research. Insights into the potential of smartphone applications are valuable for all organisations that face the issue of economic and ecological inefficiencies of human-product matchmaking regardless if they operate in an intraorganisational, a business-to-business, or a business-to-customer context. This was an early approach to employ smartphone-based technology in intraorganisational product-human matchmaking procedures for

protective clothing. Although improvements are still possible from a technical point of view, the findings suggest that smartphone-based body scanning will have a key impact on industry.

Comparative Analysis of 4D Scanning and Mobile Dynaback Sensors for Ambulatory Imaging of the Spines 22

Yordan KYOSEV 1, Jana SIEGMUND 1, Felix KUNZELMANN 1,
Ilvaylo VATOVSKI 2, Sabri MAHDAOUI 2

1 TU Dresden, ITM, Chair of Development and Assembly of Textile Products, Dresden, Germany;
2 Madesign Ltd., Sofia, Bulgaria

This study presents comparative analysis of two systems for body scanning. The optical system of the high speed MOVE4D scanner is able to provide large set of 3D point clouds and meshes of the human body during motion with high accuracy, but is available only on research laboratories and is stationary, which means, that can not be applied outdoor or working space. Contrary, the Dynaback sensors are mounted in the shirt, and can record the positions and orientations of the spine the whole day independent on the environment. The goal of this study is to provide comparative data about the accuracy, time consummation and resourced required for using both systems.

In order to obtain this information, a human, equipped with the Dynaback shirt was scanned during the motions in parallel with the MOVE4D scanner at TU Dresden at different motion sequences. The scan data of the both systems was evaluated. The optical scanning system provide large set of point clouds of the human resp. shirt body surface with high accuracy, where the sensors position can be identified. The coordinates and orientation of the sensors are compared with the data, delivered by these and quantitative and qualitative evaluation of the accuracy of the mobile system is provided.

Method for Evaluation of the Motion Comfort of the Clothing for Deaf People Using of High Speed (4D) Scanning 60

Nataliya SADRETDINOVA 1,2, Yordan KYOSEV 2

1 Kyiv State University of Technologies and Design, Ukraine;
2 TU Dresden, ITM, Chair of Development and Assembly of Textile Products, Dresden, Germany

This paper presents a short survey about the situation and amount of deaf people and the way they communicate. During the motion of the hands, deaf people require significantly more freedom in their clothing compared to the people, which can hear the voice and do not have to describe their words with hands. Typical gesture movements are scanned with a high-performance 4D scanner MOVE4D and the data is processed to homologous mesh using the scanner software. After that, a newly developed post-processing tool is applied for automatic analysis of the length changes of selected segments. Based on the analysis of the length, the extreme gestures as language postures are detected and the required length changes compensation due to material elongation or slippage is calculated. The use of the obtained data in the design of clothing for the hearing impaired will allow optimizing the cut of clothing following the functional environment.

Evaluating Fit by Using Animated Body Scan Avatars and Digital Coveralls 51

Fatma BAYTAR, Mona MAHER, Aditi GALADA

Department of Human Centered Design, Cornell University, Ithaca, NY, USA

Digital garment simulations can be very useful for technical design teams when evaluating the fit of the functional or protective garments, especially when 3D body scanning technology is unable to fully capture certain poses. In this study, we tested a method of creating animated coverall simulations and using the obj files of three poses, i.e., A-pose, reaching front, and stepping front, for objective and subjective fit analyses. We used 29 body scans that were rigged in Mixamo to analyze ease amounts of digitally stitched coveralls in each pose. Pattern outlines were visible in the digital coveralls Circumferences, cross sections, volumes, as well as crotch heights, were measured from the obj files of the clothed and minimally clothed digital bodies. Results showed that our method was effective in creating realistic wrinkles/folds that indicate tightness. There were significant differences in the overall ease across the three poses. A-pose yielded the highest overall ease followed by reaching front and stepping front. Crotch ease was significantly the lowest in the stepping front pose. Animations were found to be signaling additional fit clues.

TECHNICAL SESSION 5: 3D/4D Body Processing

Introducing the 5 Definitions, Human, Humanoid, Cover, Coveroid, Transformation 46

Carol MCDONALD

Gneiss Concept, Washougal, WA, USA

Abstract not available.

Relationships Between Rigs and Humanoid and Coveroid Landmarks 30

William GLASCOE 1, Katy SCHILDMEYER 2, Emma SCOTT 3,
Simeon GILL 4, Alfredo BALLESTER 5, Carol MCDONALD 6

1 Web3D Consortium, Burtonsville MD, USA;
2 KS Apparel Design & Consulting, Salt Lake City UT, USA;
3 Fashion Should Empower Research Group, Victoria BC, Canada;
4 The University of Manchester, Manchester, England, UK;
5 Instituto de Biomecanica de Valencia, Universitat Politecnica de Valencia, Spain;
6 Gneiss Concept, Washougal WA, USA

3D body scanning, 3D body photography, and motion capture systems, along with Coveroid creation and ideation tools still have significant interoperability gaps and user interface shortfalls. As much as consumers want to trust virtual try-on platforms, and brands want a return on investment of 3d tools via industry key performance indicators like fit-related returns, the trade-offs brands made in repurposing creation tools from the gaming industry remain insufficient for designing Coveroids (virtual apparel or garments) to fit Humanoids (avatars) of consumers. Currently, mesh construction is a painstaking process, involving joint hierarchy definition, binding of mesh vertices to joint centers, and application of weights to each joint. Apparel landmarks are equally as challenging, with many landmarks located on soft tissues that slide over the underlying skeleton and bony references moved by the Coveroid and/or body movement. The most appropriate positions to associate with vertebrae and spinal sections (Cervicale, Thoracic, Lumbar, Sacral) for the rigged model are of discussion.

Apparel Fit Language Suited to 3D Body Processing Ecosystems 41

Emma SCOTT 1, Simeon GILL 2, Susan ASHDOWN 3, Gerald RUDERMAN 4

1 Fashion Should Empower, Victoria, BC, Canada;
2 Dept. Of Materials, The University of Manchester, Manchester, UK;
3 Cornell University, Ithaca, NY, USA;
4 Zdoit, Brooklyn, NY, USA

Colloquial language, reflective of the diversity of practitioners involved in 3D Body Processing (3DBP), has proven to be an obstacle toward shared digitization efforts. Here we distill language specific to apparel manufacturing for clarity toward the shared goals of the 3DBP ecosystem. The whitepaper "3D Body Processing Ecosystem Overview" simplified the processes within the 3DBP ecosystem using four assets: cover, coveroid, human, and humanoid. From this we understand a cover to be any product, garment, or material worn on a human and a coveroid and humanoid to be the models of the finished forms. Here we build upon this foundation to consider where language fails to provide clarity crossing the physical to virtual realms within the 3DBP ecosystem. Through this discussion, apparel challenges are highlighted from both the perspective of the apparel practitioner (requiring subjective, heuristic, sensory processes) and the software architect (requiring objective, logical processes). Perspectives on fit are provided clarity for future dialogue toward cross-platform solutions suited to the 3DBP ecosystem. The terms are applicable beyond the influence of current trends or style aesthetics and therefore scalable, relevant to well established manufacturing practices, yet sensitive to the art of garment design which is, and will remain, foundational to apparel practice.

Characterizing Apparel & Fit for Virtual and Physical Worlds with Logic Statements 14

Carol MCDONALD 1, Jayamali DE SILVA 2

1 Gneiss Concept, Washougal, WA, USA;

2 Department of Textile and Apparel Engineering, University of Moratuwa, Sri Lanka

This paper conceptualizes clothing fit and represents fit attributes in detail using Logic statements with either common logic symbols or uniquely defined symbols to indicate thought process and then expand to the implemented level of Fit. These Logic statements explain the relationships between body and fit in 3D and 2D along with 1D and 0D features and measures. This work introduces four

assets: Human, Humanoid, Cover, and Coveroid; and the fit attributes depict the relationships of those assets. Subsequently, 16 transforms are combined to broadly define technology offerings involving physical and virtual fit. Importantly, the Logic statements are shown to depict proposed relationships that determine Intended Fit and Expected Fit. Fit statements were expressed for both known and unknown parameters; therefore, it can simulate a Ready-to-Wear Use Case, and Bespoke to Made-to-Measure Use Cases. In addition, 2D and 3D fit landmarks are described in the form of geometric details, including body geometries and measurement locations for known and unknown Humans and Humanoids. This work has characterized the essential parameters of Design Realm, Production process impact, and underneath cover(s). The Design Realm has incorporated: Universal style tag requirements, Emotive Design, and Human shape-dependent parameters. Since the fit is impacted by time, 4D concepts can be incorporated into a virtual avatar, in which Planned Fit is described by Rigging. This work translates all the fit principles used in the apparel industry into logical statements for both mathematicians and digital tool developers. Consequently, this will augment software intended to automate Cover design and development.

Fit Validation and Assessment Through Block Comparison 19

Emma SCOTT

Fashion Should Empower Research Group, Victoria, BC, Canada

On-demand manufacturing is integral to sustainable practices, but product returns must be avoided to reduce waste and maximize revenue streams. With garment fit being a driving cause of returns, concerted technological engagement has been directed at acquisition of data defining apparel fit. (e.g., radial ease, compression ease, fit preference, body-shape, fit mapping, etc.) Such data has somewhat improved size selection algorithms but shed little insight on quantifying fit at the garment pattern level. For example, while a flattened 3D body mesh effectively reveals the body as 2D geometry, it offers little toward the developable garment pattern as it lacks relevance to established principles of dart manipulation and pattern-making theory. This paper discusses how a 'block comparison' approach to fit assessment better translates body data to linear dimensions suitable for both changing fit at the pattern level and improving fit prediction algorithms. Discussion will elaborate how body-blocks define 3D human morphology at the garment pattern level to establish practice for quantified fit theory while supporting traditional apparel pattern practice. The change management required for fit validation (the digital asset as tech pack) lays the foundation for automated mass customization, not as the once considered singular solution, but as a scope of solutions ranging from ready-to-wear (RTW) to bespoke. Not as the once considered singular solution, but as a scope of solutions ranging from ready-to-wear (RTW), to bespoke. With sustainable garment production being a key factor in mitigating climate change, fit validation to reduce garment returns (increasing the profitability of on-demand manufacturing) is a logical next step. In this environment, both customer and brand fit preference may align or differ without imposing on the other. From here we must consider that perhaps Industry 4.0 is better embraced with a full suite of fit intent offerings, where the change management required for RTW fit validation (digital tech packs) sets the foundation for automated mass customization, not as the once considered singular solution, but as a scope of solutions ranging from ready-to-wear (RTW), to bespoke. In this environment, both customer and brand fit preference may align or differ without imposing on the other.

Method for Automatic Analysis of the Clothing Related Body Dimension Changes During Motion Using High-Speed (4D) Body Scanning 24

Yordan KYOSEV, Vanda TOMANOVA, Ann-Malin SCHMIDT

TU Dresden, ITM, Chair of Development and Assembly of Textile Products, Dresden, Germany

The high-speed (4D) body scanner MOVE4D provides the possibility to scan moving humans with high resolution and frequency. The large data set of point clouds has information about the body and clothing interaction, but requires new algorithms for its evaluation. The IBV team provides for the scanner a dedicated software, which includes algorithms to fit a body template to the scans. The scanned vertexes remain in this way consistent with the connected body parts and the mesh is homologous. This feature allows to track different distances and curves during the motion by following the same vertex between the frames without complex 3D image processing algorithms.

The current work presents a new developed specialized programming environment, which tracks curves marked on a human body surface during a motion. The curves are defined using the common file format "ini" and are based on the vertices. Then the coordinates of the vertices are extracted from the files with the consistent meshes. Finally, the curves and their lengths are analyzed and visualized.

The method allows automatic processing of circumferences and lengths of the body and provide novel information about the body size during the motion. This information will provide qualitative new information for the design of clothing with better dynamic fit, for instance close to the body sportwear, workwear and others

TECHNICAL SESSION 6: 3D/4D Body Scanning Systems and Uses III

Chris LANE, Andrew AUBREY
3dMD LLC, Atlanta GA, USA
Abstract not available.

Mathieu PERCIE DU SERT, Guillaume COURSIN
tOOiin, Sevres, France
We will present our vision of the future of digital identities in the web 3, metaverse and in the web 2. We will explain how tOOiin has started its transformation from a body scanner R&D company to become a startup specialized in digital identities, and why and how we want to develop a platform compliant with all 3D Body Scanners. not available.

Ken VARNER
botspot AG, Berlin, Germany
Summary: Advanced lighting for photogrammety based scan systems improves the robustness of high accuracy scanning across all skin tones. Furthermore, defining expectations when using automated body measurement extraction for custom tailoring will be addressed.

Thomas RICHTER, Florian KETTE
NeXR Technologies SE, Berlin, Germany
We present a future with lower returns, perfect size recommendations and virtual fitting as a one-stop solution.

Laurent JUPPÉ
VyoO, Montreal QC, Canada
Automatic measures detection. Rigid objects. Semi-rigid objects. Non-rigid objects. Automatic measures calculation. Automatic measures smart adjustments.

Eduard COJOCEA
ESENCA Ltd., London, UK
We present a novel, multi-model AI-powered approach to extract any body measurement at a pixel level, with 5 millimeters precision. Our Virtual Assistant guides the user in real-time to take two full-body photos. Our state-of-the-art Deep Learning pipeline extracts body measurements from two images using custom datasets. It uses them to dynamically and accurately build a high-fidelity 3D Model of the user's body, enabling quality visualizations of the extracted body dimensions. Finally, we will allow the user to access a True Virtual Try-On experience using their 3D Model to view how clothes of different sizes would fit them.

TECHNICAL SESSION 7: 3D Body Scanning for Medical Applications

Digitization in the Orthopedic & Prosthetic Industry: From 3D-Scan to Orthopedic Aid 05

Sonja BENNIS, Max THALMEIER, Khoi LAM, Bianca WEBER

Mecuris GmbH, Munich, Germany

In the O&P Industry, digitization allows for a faster and more precise process to create customized orthopedic aids. From 3D Scanning to a printed orthopedic aid, it is however a challenge to integrate these technologies into a traditional industry.

Feedback Mechanisms of an iOS App to Record RGBD Data for AI-Based Diagnosis and Monitoring of Infant Head Deformation 39

Fabian RAPP 1, Samuel ZEITVOGEL 3, Christian MEDER 1,
Kai STOEVESANDT 2, Christian WERNET 3, Astrid LAUBENHEIMER 3

1 inovex GmbH, Karlsruhe, Germany;
2 VARILAG GmbH & Co. KG, Ettlingen, Germany;
3 Intelligent Systems Research Group (ISRG), Karlsruhe University of Applied Sciences, Germany

We present a prototype of a 3D infant head reconstruction app on a mobile phone for a cranial asymmetry measurement method. In this work, we focus on the user experience and user feedback of the interactive reconstruction pipeline.

The advent of 3D sensor-equipped mobile phones such as the iPhone TrueDepth camera enables widespread 3D reconstruction and measurement applications such as room measurements for interior design preview and object reconstruction. Reconstructing an infant's head with an RGBD sequence is challenging due to the uncooperative behaviour of the subject.

The RGBD data for the scan is recorded with the TrueDepth camera system on the front of iPhones (starting with the iPhone X), which is normally used for FaceID. The forward-facing position of the sensor poses a challenge to the app operator because the screen is hardly visible during recording.

The major contribution of this work is an app providing audible, haptic and visual feedback to support the user during the scanning process. Furthermore, the app is designed to be easy to use following an intuitive user experience design. Lastly, the developed app is tested by a team of physical therapists to evaluate the feedback concept and the user experience.

Comparison of Optical Handheld 3D Scanners Suitable for Prosthetic and Orthotic Applications 06

Branko STEFANOVIC, Bibiana ONDREJOVA, Lucia BEDNARCIKOVA,

Teodor TOTH, Jozef ZIVCAK

Technical University of Kosice, Faculty of Mechanical Engineering,
Department of Biomedical Engineering and Measurement, Kosice, Slovakia

3D scanning technology is globally frequently used in the field of prosthetics and orthotics. Techniques and methods using 3D scanners make it easier and faster for CPOs (Certified prosthetic orthotist) to obtain important data for prosthetic and orthotic device design.

Nevertheless, in low-income countries, this is still a new approach, and some CPOs might find it hard to trust. Also, the prices of some of these 3D scanning devices and data processing software are too high. Because of these issues, modern methods are being neglected and the whole prosthetic device designing process isn't advancing.

The aim of this study is to compare optical handheld 3D scanners of different brands, designs, and price ranges. A polystyrene model of the human torso with predetermined geometric forms will be scanned with multiple handheld optical 3D scanning devices. For the precision evaluation of the 3D scanners and hand measurement it is necessary to position the reference forms in a way that it will allow measurement by both methods. Selected dimensions must include all three axes of the cartesian coordinate system, so it will be possible to scanners precision in all individual axes. Scanning will be performed by one person in a room with stable lighting and room conditions. The torso model will be scanned by individual scanners and measured by hand 3 times and a mean value and standard deviation will be calculated. The geometric forms will be also used for the alignment of obtained 3D models in VGStudio Max software, which will be used for the analysis process. Distances between predetermined forms on the obtained 3D models will be evaluated. These nominal values will be compared with the actual values from the torso model, which were measured by hand.

The quality and surface precision of actual obtained 3D models will be compared to determine the minimal or ideal requirements of optical handheld 3D scanners for the use in the field of prosthetics and orthotics.

SMART Eyebrow Micro Blading & Hair Transplants using AI 62

Seyed Soroush VALINIA

SMART Beauty, Istanbul, Turkey

Achieving the ideal results through eyebrow cosmetic treatments such as microblading or eyebrow transplant can be challenging. The challenges in these procedures are selecting the ideal form to suit the clients' face and satisfy their needs, implementing the chosen form on the clients' face, and stating the eyebrows' symmetry. This talk highlights two newly developed methods that increase the accuracy of eyebrow cosmetic treatments. These two methods indicate how the combination of 3D technologies, artificial intelligence (AI),image processing, and computer vision can help achieve the ideal results through such treatments. Moreover, in this talk, the newly designed software AIbrow is also introduced.

TECHNICAL SESSION 8: 3D/4D Body Scanning for Apparel II

Custom-Fitted Apparel at Scale: Challenges & Solutions 32

Taime KOE

Six Atomic, Singapore

Examine major challenges in making custom-fitted fashion scalable, from the reusability of inventory, to production line configurability, and addressing customers' fit preferences. Explore the latest technologies to solve them.

Innovative Breakthrough with Bespoke 4D: How to Directly Create 3D/4D Garment 61

Alexandre KUNG

Made To Form (MTF), Geneva, Switzerland

Abstract not available.

A Pilot Study Using a Remote, AI-Powered Measurement Technology to Enable a Decentralised Production System, from Ideation to Delivery 20

Colette JOHNSON 1, Francesca DONADONI 1, Thakane BAZILL 2

1 The PS Collective Inc., Brooklyn, NY, USA;
2 TAKAII U.G., Cologne, Germany

Our AI-powered, contactless measurement solution has been recently introduced to provide a cost-effective and scalable platform for designers to obtain reliable measurements remotely. With the recent rise of digital fashion, there has been a move towards more rapid iterations of the design process and streamlining of the supply chain, with an outlook on producing more sustainably. In light of these recent developments, we tested how our remote solution for contactless measurement could be used as part of a decentralised production process for small-batch designers in different geographical areas.

Five digital fashion designers provided design artwork in 3D format, to be tailored to each of the customers' sizes. At the start of the pilot project, each customer was asked to submit two full-body images, front and side, for the AI platform to calculate the measurements. Of the five designers, 1 provided pre-cut fabrics, 2 provided fabric only, and 2 sourced and cut the fabric at the same location where tailoring took place, so that different processes could be tested.

The process from submission of the images by the customers to delivering the final measurements to the designers was completed within one hour's time and with positive feedback from the designers. The designs were adapted to each of the customers' measurements to form 3D patterns. Pattern making and tailoring took place in Accra, Ghana, where the fabrics were also sourced. The final items were delivered directly to customers.

This pilot study showed the potential for accomplishing a new production system that will create customized items on demand and regardless of geographic location, using a universal measuring system based on objective measurements from image data. Using The PS Collective's contactless, remote solution for measuring customers' sizes it was possible to streamline the design process with

minimal movement of designers, pattern-makers, and customers. On a larger scale, this solution has the potential to enable a more sustainable production process, without sacrificing the quality that comes with made-to-measure.

Virtual Fit Platforms in Fashion E-Commerce 34

Michela ORNATI 1,2, Anna PICCO-SCHWENDENER 1, Suzanna MARAZZA 1

1 Universita della Svizzera italiana (USI), Switzerland;
2 University of Applied Sciences and Arts of Southern Switzerland (SUPSI), Switzerland

Dress is an embodied experience which is dematerialized online. In a fashion e-commerce website, clothes cannot be touched, nor worn prior to purchase and delivery; this engenders issues of fit and thus, returns. To solve this issue, fashion companies are turning to size recommendation and virtual fit service platforms. Simply put, virtual fit systems algorithmically match customer body data to fashion items which are potentially the right size and fit. This process aims to create value for all parties involved: for brands, by improving customer satisfaction and reducing returns; for customers, by facilitating choices; and for platform providers, by the sale of services and tools. However, as research in online platforms in other fields suggests, virtual fit services are driven by mechanisms of datafication, curation and commodification of fashion consumers' bodily data - which in turn raise issues related to privacy and inclusivity. To the best of the authors' knowledge, virtual fit platforms and their effects on the datafication of dress embodiment have heretofore not been discussed in fashion studies literature. This article spotlights the growing phenomena, opening avenues for further research in the field.

TECHNICAL SESSION 9: 3D Foot Scanning

Deep Learning Assisted Product Grouping for Shoe Size Recommendation 63

Eugene BULOG 1, Calli BATES 1, Naomi NORTH 2, Tsuyoshi IETA 2, Bo LI 1

1 ZOZO New Zealand Ltd., Auckland, New Zealand;
2 ZOZO., Tokyo, Japan

Shoe size recommendation tailored to specific products and users is a complex problem influenced by many factors. These include not only user-based attributes such as individual 3D foot shape and preferences, but also the sizing properties unique to each model of shoe. Large scale data collection and grouping of shoes based on the way they fit users is a crucial step towards being able to recommend to a user their perfect size in a specific item of footwear, down to the brand and product level.

This work presents a scalable and robust platform to facilitate AI-assisted grouping of footwear SKUs, allowing businesses to rapidly aggregate shoe products into groups containing similar items across multiple retailers with the exact same fitting properties, which can then be used to train a family of bespoke size recommendation models. These recommendation models use a combination of learned properties of each shoe and 3D foot scan data from users to predict a personalized ideal fitting size.

The platform leverages "human-in-the-loop" machine learning, by presenting highly accurate grouping predictions (generated by a deep learning triplet loss model) to human supervisors for quick confirmation. This provides a much faster alternative to humans combing an enormous list of products and manually cross checking each product against all existing groups.

Use of this platform has greatly accelerated the ability of our shoe size recommendation product (ZOZOMAT) to support new models of shoes - by automating the most time-intensive and error-prone aspect of grouping shoes for training and prediction. This results in more accurate and granular shoe size recommendations for users, and lower customer return rates in purchased shoes.

Improving 3D Registration Results of Foot Models Dramatically with a Machine Learning Enhanced Geometric Feature Extraction 43

Tobias PFROMMER

ShoeFitter GmbH, Konstanz, Germany

In this paper, a method is presented that enables a true-to-scale reconstruction of 3D foot models using the iPhone's Face ID sensor. For this purpose, multiple incoming 3D point clouds representing the foot are registered piece by piece with each other. A feature-based registration pipeline is used for pairwise registration. Geometric feature extraction in such pipelines is the first and most important step for correct registration of two 3D point clouds. For this purpose, we train and apply learned feature

descriptors based on Fully Convolutional Geometric Features (FCGF). It is shown that the features computed by our trained feature extractor are more robust and faster than conventional methods. We trained FCGF using a self-generated dataset of 3D foot models augmented with synthetic data. The trained feature model was optimized with hyperparameters. For better visualization of the high-dimensional features, a t-SNE-based visualization is used to assign features that are reliably found in the same location of the foot in different models. Based on the detected features, the optimal transformation of two point clouds is estimated by a feature-based RANSAC algorithm. In the benchmarks, it is found that the implemented feature descriptor consistently achieves better feature matching and registration recall results than comparable feature descriptors. With the final trained model of the feature descriptor within the presented registration pipeline, a 3D reconstruction of a foot can be performed using an overlap of only 27 percent. This makes the reconstruction of the 3D model much more robust than using comparable state-of-the-art methods.

Automatic Foot Measurement Extraction from a 3D Point Cloud via a Deep Neural Network 47

Nastaran NOURBAKHSH KAASHKI, Xinxin DAI, Pengpeng HU, Adrian MUNTEANU

Department of Electronics and Informatics, Vrije Universiteit Brussel, Brussels, Belgium

The foot is a vital human body part comprising a complex system of muscles and bones sustaining the human weight, and providing balance and mobility when daily activities are being performed. Extracting accurate foot measurements is of paramount importance in many applications including medical sciences, sports and fashion industry. Traditionally, footwear brands employ contact-based foot measuring methods involving a trained operator to design and produce well-fitted footwear products. However, this process is very time consuming and is prone to human errors. With the advancement of 3D scanning technologies, the foot can be scanned accurately with an affordable 3D scanning device. In this research, we propose, to the best of our knowledge, the first deep neural network (FNet) for automatic foot measurement extraction from a 3D foot point cloud. The proposed FNet is an encoder-decoder neural network which operates on the foot point cloud and outputs the foot reconstruction as well as the corresponding measurements points utilized for measurement extraction. Our study shows that teaching the network to accurately generate the measurement points, performed with the help of the well-designed loss functions, is necessary for automatic and accurate foot measurement extraction. In order to train the proposed neural network, a large dataset of complete foot scans with their corresponding measurement points and measurement values are synthesized. The performance of the proposed method has been evaluated on both synthetic test data as well as the real scans captured by the Occipital Structure Sensor Pro. The results show that our method outperforms the state-of-the-art methods in terms of accuracy and speed.

Analysis of Hallux Valgus Angles Using 3D Foot Scans 56

Ales JURCA 1,2, Yang JIAO 1, Saso DZEROSKI 2,3

1 Volumental AB, Stockholm, Sweden;
2 Jozef Stefan International Postgraduate School, Ljubljana, Slovenia;
3 Jozef Stefan Institute, Ljubljana, Slovenia

Hallux valgus angle (HVA) indicates the medial side of the forefoot shape. Radiography during weight bearing and goniometers are commonly used methods to measure HVA. The use of 3D scanning technology in footwear retail has enabled to collect large quantities of foot scans, and analyzing the variety of HVA in a population.

A dataset of over 25,000 foot scans of female 3D foot scans in length class 245mm was used in this study. The dataset was collected with Volumental 3D retail foot scanners, located in footwear stores in North America. An automatic algorithm was used to extract HVA from each foot scan.

Results show a large dispersion of HVA: the 5th percentile is equal to 2 degrees and the 95th percentile is equal to 24 degrees. The mean HVA is 11.7 +- 6.9 degrees. 26% of the feet have HVA larger than 15 degrees, which indicates hallux valgus - the most common forefoot deformity. These results may assist footwear brands in improving the design of footwear toe boxes to better fit the feet of their customers, and to reduce the occurrence of hallux valgus

TECHNICAL SESSION 10: Metaverse & Avatars

The Key to an Open, Functional, and Interoperable Metaverse 27

Anita HAVELE 1, Nicholas POLYS 2, William BENMAN 3

1 Web3D Consortium, USA;
2 Virginia Tech, USA;
3 Integrated Virtual Network, USA

The term 'Metaverse' has taken on a new sparkle recently, appearing prominently in the marketing materials of several large technology companies. Indeed, many have attempted, or are attempting, to co-opt it for their own purposes, which has resulted in a great deal of confusion among producers and consumers in the marketplace. Is the metaverse a single walled garden, shared game, or social environment? Or will the metaverse be an open unified space suitable for education, ecommerce, entertainment, and industry applications? How will we move ourselves and our content seamlessly between real, virtual, and augmented worlds? How will we ensure security and provide for user-control of personally identifiable information (PII) or health data? The metaverse may well find itself at the intersection of social interaction, industry applications and virtual expressions, the essence of the global apparel and wearable industries. With this in mind, we must ask ourselves, what the metaverse might mean for the apparel industry and its current outlook and its future.

With this short position paper, the Web3D Consortium seeks to address this confusion by exploring the history of 3D visualization and its formats, that has led us to our current state, providing a workable definition of the term 'Metaverse', and providing a vision for its sustainable, cooperative construction into the future. We believe that all the technologies are in place to fulfill the vision of an open, equitable, and ubiquitous information space. What remains are the key issues that have kept the Metaverse from manifesting the last two decades: user experience.

Analyzing the Gap between Physical and Digital Fashion 54

Arzu VURUSKAN, Ece SAHIN

Izmir University of Economics, Department of Textile and Fashion Design, Izmir, Turkey

After the launch of the metaverse, digital fashion has been given more attention by fashion brands. In addition, the gaming and fashion industries' paths became intertwined through fashion items. However, in-game cosmeticsi and real-life fashion garments are quite different in terms of material and style, i.e., there is a clear gap between digital and physical fashion. Due to its flexibility, digital fashion can easily be differentiated from physical fashion. This research aims to highlight the gap between digital and physical fashion in video games. For this purpose, a survey was conducted with 100 gamers. After collection from the participants, the data was reviewed, and accordingly, a sample game was chosen for this research. In order to narrow the gap between digital and physical fashion, a capsule collection was designed for the game called "League of Legends". Three pairs of outfits, one version for digital fashion and one for physical fashion, were prepared in 2D and 3D. The outfits were designed to suit the chosen characters. Such approaches can allow consideration of points of similarity for the pairs of designs, enabling adaptation to the digital world. As a result, the gap between digital and physical fashion can be narrowed and more realistic garments can be created for video games, which are able to satisfy and even inspire gamers.

Optitex Avatar Framework Enables Modelling Agencies and Mannequin Providers to License Digital Replicas of Their Models for Fashion Brands and Manufacturers 65

Maria LANDO

Optitex, Rosh HaAyin, Israel

For over 30 years Optitex has been creating technologies for fashion brands to design and produce apparel for any gender, age and size. Covid isolation needs, growth in eCommerce, expansion to further markets, and technological advances in cloth simulation and material rendering facilitated fashion shift to a mainly digital sampling. This highlighted the demand for realistic-looking virtual models in all sizes and shapes for try-on sessions, fit analysis, collection reviews and marketing presentations. Many modelling agencies and mannequin companies rushed to digitize and virtualize their offering. But the process left virtual model protection out of the picture. Like a snapshot shared on Instagram, 3d virtual representation of you could enter the world wide web and be used for many useful and creative or malicious purposes.

For real-life models and mannequin providers to benefit from "leasing" their services, protection of IP and monetization are critical needs that must be addressed. NFT technologies are starting to be applied to virtual 3D items, but the enforcement policies are still not clear.

At Optitex we designed a framework that essentially mirrors in a digital domain the long-existing relationships between brands and their modelling agency or mannequin providers. Modelling agencies and mannequin providers get easy avatar virtualization and encryption, as well as a simple way to define brand and vendor access rights to "lease" each such virtual avatar. Behind the scenes Optitex takes care of maintaining these access rights and assuring authorized-only use of virtual models for cloth design, simulation and fit analysis. Additionally, our technology guards virtual model distribution in any open format without specific model authorization. Pure virtual models remain to be in the property of their owners while these owners are able to lease the encrypted copies to brands and vendors directly, monetizing their IP.

Optitex's Avatar Distribution Framework creates a vast opportunity for Modelling agencies and mannequin providers to extend their business to brands and vendors to which they had no access before, and to license and price their services in new ways that fit the digital age.

Meshcapade's Avatar as a Service Platform 66

Naureen MAHMOOD

Meshcapade GmbH, Tuebingen, Germany

Abstract not available.

TECHNICAL SESSION 11: Digital Anthropometry & Ergonomics

Moving 1-1 Custom Fit to Everyday Consumers at Normal Prices. How THEMAGIC5 Did That. 72

Bo HAABER

THEMAGIC5 Inc., Charlotte NC, USA

THEMAGIC5 (https://themagic5.com) is delivering custom fit swimming goggles to both competitive swimmers and recreational swimmers. The whole process from customers purchase on our web-site, over providing your scan through our app, through our optimal fitting technology, to 1-1 production and world-wide shipping. 1-1 custom fit consumer products is typically only for +$500 products, but THEMAGIC5 has through our innovative technology and constant focus and collaboration with our customers, broken this rule and are able to sell our 1-1 custom fit swimming goggles at the same price as other off-the-shelf products ($55/unit). THEMAGIC5 has done this more than 150,000 times.

But it does not stop there. THEMAGIC5 has two more products in the workings.

Co-founder and CEO, Bo Haaber will talk about how THEMAGIC5 did that, and what to expect next from the company.

Population-Wide Facial 3D Database-Based Validation and Modification of a Filtering Half-Mask 3D Design 10

Mikolas JURDA, Martin CUTA

Department of Anthropology, Faculty of Science, Masaryk University, Brno, Czech Republic

Introduction: In the initial phase of the COVID-19, a shortage of appropriate PPE became evident, leading to serious problems in controlling the spread of infection. One of the public responses was the decentralized production of new protective half-masks designs that took advantage of the flexibility and availability of 3D printing technology. However, the initial designs suffered from a lack of data on the Central European craniofacial variation. As a result, the masks weren't properly shaped, which compromised comfort and protection from viral droplets. This study summarizes the validation and modification of such a half-mask design for subadult individuals based on an existing population-wide database of 3D facial scans.

Material: Numerical and virtual validation of fitment was performed on a sample of 1137 individuals (619 females and 518 males) aged 4.06 to 18.94 years represented by facial 3D scans from the FIDENTIS 3D face database. Each scan was supplemented by 3D coordinates of seven landmarks identified on the scans according to the protocols and definitions of FIDENTIS 3D Face Database.

Methods: The proposed design of a subadult half-mask was confronted with the population craniofacial variation in terms of dimensions and direct superimposition of the 3D models within the virtual workspace of Blender 3.1 software. Subsequently, four new size categories were defined based on a facial centroid size, covering the whole size variation of the available sample. Finally, the four adjusted half-mask designs were assessed by a comparison with the average facial shapes of the subadult categories.

Results: The population-wide 3D databases enable rapid and flexible validation and modification of the PPE designs. The experience with the COVID-19 pandemic further augmented the significance of such ready to use, non-specific 3D morphological data. Obtaining such a sample would have been nearly impossible under the movement restrictions of the time.

Reliability and Accuracy of Mobile 3D Scanning Technologies for the Customization of Respiratory Face Masks 44

Arthur AGOSTINI 1,2, Aude CASTONGUAY-HENRI 1,
Sean-Philippe VIENS 1, Jonathan BORDUAS 1, Luc DUONG 2

1 Technologies Shapeshift 3D Inc., Montreal (QC), Canada;
2 Ecole de Technologie Superieure, Montreal (QC), Canada

This article compares the reliability and accuracy of face-scanning technologies used in the context of head reconstruction. The goal of this study is to provide recommendations as to which technology is suitable for customizing respiratory face masks. Two technologies will be analyzed; ARKit: Face Tracking SDK by Apple using an iPhone XR, and Structure Sensor by Occipital using the 3DSizeMe app with an iPad Pro 5th generation. As ARKit only generates a mesh on the face, the Flame AI framework is used to extrapolate the full head shape.

Reliability and accuracy were determined through a series of standard measurements taken on each reconstructed scan of a series of 48 male and female retopologised head scans obtained from the 3D Scan Store. Each head was 3D printed and scanned three times with both ARKit and the Structure Sensor. A deep-learning model was used to identify 73 standard landmarks on each face from which were derived 11 anthropometric measurements defined by the ISO 16976-2:2015 part 2. The anthropometric measurements were compared between scans of a single face for reliability and compared with the initial head form for accuracy.

Context: In 2021, the production of off-the-shelf single-use N95 masks had almost quintupled since the Covid-19 outbreak in 2019. Healthcare professionals must now wear a mask at all times when treating patients. They thus wear masks every day for extensive periods of time. The airtight seal required to guarantee efficiency sometimes requires excessive pressure depending on the morphology. This, coupled with the prolonged use, often causes discomfort and injuries. This issue led to a worldwide effort to develop custom-fitted respiratory masks. The advantage of designing a custom-made mask based on the 3D scan of the face is ergonomic and improves user comfort over extended periods of time.

Comparing Univariate and Multivariate Analysis of Anthropometric Measurements from 3D Body Scans for Ergonomic Work System Designs 13

Alexander ACKERMANN, Sascha WISCHNIEWSKI

Federal Institute for Occupational Safety and Health (BAuA), Dortmund, Germany

To design ergonomic workplaces, planners need, among other things, anthropometric data to fit the work system to the physical body dimensions of the user group. In this design process, a general distinction between univariate and multivariate approaches can be made, if several anthropometric measurements need to be considered. The aim of this publication is to present the univariate percentile approach as well as the multivariate principal component analysis (PCA) approach and to discuss differences in the resulting total accommodation (TA). A seated office workstation with visual display terminal served as a generic use case, resulting in ten relevant ISO 7250-1 measurements. The utilized anthropometric dataset, consisting of 2313 subjects (1161 men and 1152 women), was gathered between 2014-2019 within an epidemiological health study in northeast Germany, using a Vitus Smart XXL Body Scanner. With the defined use case and user group, the univariate percentile approach and the multivariate PCA approach were performed separately for the male and female subset to achieve a desired TA of 90%. In the male subset, the total accommodation was 52.7% for the univariate percentile approach and 78.3% for the multivariate PCA approach. In the female subset, the total accommodation was 51.8% for the univariate percentile approach and 78.5% for the multivariate PCA approach. Therefore, given a multidimensional use case and an anthropometric dataset in an

ergonomic design process, the results of this publication indicate that it should be examined whether a multivariate approach is superior to a univariate approach to achieve an adequate TA.

Robust Body Shape Correspondence with Anthropometric Landmarks 17

Yibo JIAO 1, Chang SHU 2, Dinesh K. PAI 1

1 University of British Columbia, Vancouver BC, Canada;
2 National Research Council Canada, Canada

We propose a method to improve the robustness of state-of-art learning-based methods for finding point-to-point correspondences of 3D human models with anthropometric landmarks. Specifically, current deep learning-based methods generally focus on intrinsic, local, properties of body shapes, which lack extrinsic global information. Thus, these methods are challenged by matching ambiguities, for instance, due to the bilateral symmetry of human body shapes. We demonstrate our method with an unsupervised learning-based method, DeepShells. Our work introduces a landmark supervision method based on the Shells by adding linear soft constraints to minimize this problem that we term the "intrinsic feature ambiguity problem." To that end, we derive a simple but efficient pipeline that better distinguishes self-similarities yet has similar overall matching quality.

TECHNICAL SESSION 12: 3D/4D Body Scanning for Apparel III

Evaluation of 3D Body Scans from Mobile App via Virtual & Physical Try-On Garments 37

Evridiki PAPACHRISTOU 1, Despoina KALAINTZI 2, Nikolaos BILALIS 2

1 Creative Design & Clothing, International Hellenic University, Thessaloniki, Greece;
2 School of Production Engineering & Management, Technical University of Crete, Chania, Greece

This paper evaluates the accuracy of mobile 3D scanning technology in regards to exported anthropometric data and 3D body mesh, when comparing the virtual try-on of a bodice with the fit on the same physical body. Fashion students during their subjects of Virtual Prototype and 2D Pattern Design Systems, divided in groups, used Mobile Fit app by SizeStream to provide a 3D representation of a body of their choice. They used the extracted obj file into CLO3D as an avatar. With the extracted anthropometric measurements the students developed a basic bodice in Polypattern 8.4v2 22 Cad pattern design system. The exported dxf files of the basic bodices were imported in the 3d environment to virtual dress the scanned body/avatar. At the same time, the physical bodice was constructed by each team and dressed on the same scanned body. Evaluation of fit was conducted comparing the two methods. Authors state the pros and cons of the complete digital method.

Comparative Assessment of Validation and Reliability of Sizestream 3D Scanner for Human Body Measurement Using Two Different Approaches 52

Manoj TIWARI 1, Noopur ANAND 1,2

1 National Institute of Fashion Technology, Jodhpur, India;
2 National Institute of Fashion Technology, New Delhi, India

3D scanning has evolved as one of the most advanced and accurate technology to measure humans and products. Quick and reliable results achieved by 3D scanning over manual measurements, make it the most preferred tool for measurement. 3D scanning has been extensively used in various national sizing surveys worldwide, including the INDIAsize (the National Sizing Survey of India) being carried out by the National Institute of Fashion Technology, INDIA. The 3D scan results are compared to the manual measurements to establish the accuracy of the scanner. This research paper describes two novel and alternative approaches (based on 1. Bias-shift, and 2. Regression modeling) to check the reliability and validity of the measures derived from 3D Body Scanner in comparison to measures provided by the manual measures. A comparison of both the approaches has also been discussed in this research paper.

The 3-D Body scanning was done by Sizestream 3D Body Scanner - SS14. The manual body measurements were taken by experienced experts using an anthropometer, stadiometer, and certified flexible non-stretchable steel tape. In total 133 subjects (68 male and 65 female subjects) covering 102 body dimensions were taken manually and were used while comparing 3D scan measurements to establish the validity and reliability of the scanner. The procedure adopted for validation and reliability check for the 3D scanner was as prescribed in the ISO 20685(2005) and ISO 20685 (2018). It was observed that the Sizestream - SS14 scanners used were highly consistent in measuring the subjects

as confirmed by the high values of Intra-class correlation coefficients (ICC) conducted to check for the consistency and repeatability between different scan measurements. However, a systematic error was reported in the process failing some of the measurements in terms of accuracy levels (as per ISO 8559 (1989) and ISO 20685(2005)) achieved against manual measurements used as the gold standards. Subsequently, two different approaches were applied to establish scanning accuracy and comparative analysis of results has been carried out.

This research paper describes the validation and reliability procedure as per ISO protocols. It also discusses the regression-based statistical procedure adopted to confirm the desired measurement accuracy of the scanners within the permissible error limits of ISO 20685 (2005) and ISO 8559 (1989). Based on the comparative analysis, the paper also suggest recommended approach to achieve the desired accuracy by overcoming the systematic error in scanner measurement for all the anthropometric dimensions. This may help in making the data acceptable for use for any further analysis.

Comparison of 3D Body Scanning Mobile Applications:
A Study of MeThreeSixty and 3D Look Mobile Apps Body Measurements 33

Sadia IDREES, Gianpaolo VIGNALI, Simeon GILL

The University of Manchester, Manchester, UK

Clothing industry around the globe frequently used human body measurements for garment production. The study aims to determine the potential of 3D body scanning feature of mobile application for product development and selection of right size and fitted garment using fashion e-commerce platform. Digital measurement methods have been introduced recently and developed extensively replacing the traditional manual measurement techniques. The paper addresses to determine the practicability of digital measurements acquired from 3D body mobile scanners in terms of reliability and validity. Formerly, for size and fit recommendation and visualisation, using technology driven interfaces user interaction was approached in terms of receiving body size and shape information manually as well as past purchase history of a garment. However, recently the web 3.0 metaverse fashion technology feature such as 3D body mobile scanners have the potential to enhance the fashion virtual size and fit e-commerce platform for online apparel shopping. Therefore, 3D mobile scanners would be helpful to enrich the accuracy of garment size and fit prediction and garment construction for online shoppers without using user's manual information input in the interface. An exploratory quantitative study has been conducted. The two mobile application scanners (3D Look and MeThreeSixty) have been studied for this paper. The digital body measurements have been analysed comparatively to determine the difference of body measurements extracted from both applications for each participant. Reliability comparison have been estimated in terms of Standard allowable error (cm) of Measurements. Validity was analysed according to ISO 20685 (BS ISO 20685, 2010). The reliability of 3D body scanning technologies has been evidenced in various studies. The Pakistani female, age 18-65+ years has been recruited to participate in the study. The data has been collected by self-scanning method using their own smartphones at home. The mobile applications are available free for users on both Android and iOS.

Measuring the Human Body from a Single Camera,
with Applications to the Clothing and Fashion Industry 11

Mohammad MONTAZERIAN, Frederic FOL LEYMARIE

Goldsmiths, University of London, Computing Dept., London, UK

Using a single RGB camera to obtain accurate body dimensions rather than measuring these manually or via sophisticated multi-camera or laser-based sensors, has a high application potential for the apparel (fashion) industry.

We present a system that estimates upper human body measurements using a set of computer vision and machine learning technologies. In a nutshell, the main steps involve: (1) using a portable camera (such as with a smartphone); (2) improving the image quality; (3) performing a calibration step; (4) extracting features of the body from the image; (5) indicating markers on the image semi-automatically; (6) producing refined final results.

We experimented with the system on a sample of participants. The results for the upper human body measurements in comparison to the main manual method of tape measurements show +-1cm average differences, which is a good enough result for a number of applications.

BodiData's Measure.Match.Manage. Size-Matching Solution 35

Tuoc LUONG

Bodidata Inc., St. Petersburg, FL, USA

In October of 2018, I introduced BodiData's Kora multi-sensors (optical depth and milli-meter wave) handheld 3D body scanner that was in development but not yet released. Fast forward to today and we have released version 2 of our patented and award-winning Kora handheld 3D body scanner - the only handheld that captures the underlying body measurements of fully clothed individuals in regular streetwear. This technology and capability do not exist anywhere else in the industry.

I will discuss Kora as part of BodiData's Measure.Match.Manage. size-matching solution that helps apparel companies dramatically reduce returns and environmental waste, while improving wearer satisfaction and increasing institutional knowledge.

Our solution recognizes that successful size-matching technology must Measure Accurately, Match Skillfully and Manage Wearer's Understanding of Fit.

Besides Kora, BodData has 3 other body measurement solutions. I will discuss and demonstrate every available handheld body measurement solution including a self-measured predictive, Video with LiDar, 2-photos and our patented and award-winning Kora handheld 3D body scanner.

I will also demonstrate our ability to Match Skillfully with not only recommending the optimum clothing size for the body scanned but also inform the wearer how the clothing size will fit critical parts of their body like the chest, waist, hip, and thigh.

Below are examples of the optical clouds we generate from our 3D body scan and the 3D radar body surface reconstruction we perform.

I have also attached examples of our ability to Match skillfully ready-to-wear clothing style and sizes to the scanned body of the individual. We not only give the best size recommendation but also inform the wearer of how each clothing size would fit critical parts of her body.

We believe our Measure.Match.Manage. size-matching solution and offering of every available handheld body measurement is worthy of discussion and sharing.

TECHNICAL SESSION 13: Anthropometric & Sizing Studies

Customer Specific Size Surveys - Solutions and Experience 31

Matthew BENNETT

Human Solutions of North America Inc., Morrisville NC, USA

Abstract not available.

INDIAsize - Planning & Execution of National Sizing Survey of India 38

Noopur ANAND 1, Manoj TIWARI 2

1 Department of Fashion Technology, National Institute of Fashion Technology, New Delhi, India;
2 Department of Fashion Technology, National Institute of Fashion Technology, Jodhpur, India

Research studies conducted on fit and human-body measurements across the globe indicates that a large percentage of consumers face difficulty in finding clothes that fit them perfectly according to their body shapes and sizes. The overarching reason is differences in anthropometric built of people from one region to another. This has led countries to undertake national sizing surveys to create anthropometric database of measurements which is a true representation of the entire population, to cater to their respective retail industry. The size charts and insights generated through these surveys and corresponding analysis has helped the garment industry to provide well-fitting garments designed as per the body structure of the native population. India is facing the same dilemma. The Indian apparel industry uses size charts which are largely tweaked versions of size charts of other countries and are created more out of the manufacturer's instinct and experience than a proven scientific study, resulting in fits which leave lot to desire. Projected returns of the garments are in the range of 30% to 40% (and is increasing with the growth of ecommerce) and the major reason for the returns are poor garment fit. Providing well-fitting garments in the absence of standardized size chart is proving to be a big challenge for the domestic textile and apparel industry in India Hence, India is undertaking its own anthropometric survey-INDIAsize, to develop standard body sizes for Indian apparel sector to address the prevailing disparities and inconsistencies in apparel sizing systems and provided fits. INDIAsize targets at collecting anthropometric data from representative Indian population, of youth, adult and

elderly, calculated basis stratified sampling of Census data of India. Data is being collected from various demographics of age, region, sex, income and community (rural and urban) using non-contact, human safe 3D whole body scanning technology. More than 25000 (Twenty-Five Thousand) male and female persons between the age group of 15 years and 65 years are being scanned in six major cities located in six regions of India i.e., New Delhi (North Region), Chennai (South Region), Kolkata (East Region), Mumbai (West Region), Hyderabad (Central Region), and Shillong (North-East Region). The anthropometric data on more than 120 anthropometric points are being extracted in two postures i.e., Sitting and standing from the participants of the survey. The survey is guided by various ISO protocols of 8559, 7250, 20685 etc. The survey will create Size identification number for a customer through mapping, categorization and defining of their body shape and size. This indigenous body size chart thus created will help national and international retailers and manufacturers to produce goods which are best suited for Indian body types and create a balance between demand and supply of well fitted clothes. The paper shares the details of planning this large-scale survey and data collected so far.

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Hometrica Consulting - Dr. Nicola D'Apuzzo
Contrada Maggiore 2, CH-6612 Ascona, Switzerland
Tel: +41 91 7915524
Email: info@hometrica.ch
Web: www.hometrica.ch
3DBODY.TECH website: www.3dbody.tech