



Book of Abstracts

6th International Conference on 3D Body Scanning Technologies

Lugano, Switzerland, 27-28 October 2015

Editor and Organizer

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Switzerland
www.hometrica.ch



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INTRODUCTION

Conference director's message #00

Nicola D'APUZZO

Hometrica Consulting, Ascona, Switzerland

The 6th International Conference and Exhibition on 3D Body Scanning Technologies will take place from 27 to 28 October 2015, in Lugano, Switzerland.

The first five international conferences of 2010, 2011, 2012, 2013, 2014 were all largely attended with over 200 participants from different countries, different technical fields and different industries.

The rich technical programs of the five events included a wide variety of works related to applications, developments and research on 3D body scanning from all over the world.

The conferences were accompanied by parallel exhibitions featuring live demonstrations of 3D body scanning equipment and solutions. Various manufacturers had chosen our events for presenting and announcing world and international premieres.

The past five events were also the occasions where births of new collaborations took place, as for example 3dmD (USA) and Max Plank Institute (Germany), TC2 (USA) and SpaceVision (Japan), UCS (Slovenia) and ElinVision (Estonia).

The success of the fifth edition of 2014 with over 250 attendees confirmed again the 3DBST conference as the most important international event for the sectors related to 3D body scanning technologies. With the sixth conference and exhibition of 2015, we will continue the role as the world leading technical and scientific platform dedicated to these specific fields.

This book of abstract is divided in sections according to the conference's technical program and it includes the abstracts of the presentations and/or of the papers published in the proceedings of the conference. The corresponding papers (if available) can be easily found in the digital proceedings by the paper id number indicated in the table of contents and after each abstract's title.

TECHNICAL SESSION 1: MEDICAL SCANNING SYSTEMS

Medical-Grade 3D-Shape Measurement by Real-Time Matching of Area Scans

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The medical use of 3D-shape data puts high requirements on data quality with respect to their reliability, accuracy and traceability. This becomes in particular important if multiple perspective views have to be combined in order to obtain 360° shape from a single scan unit. The paper will show how high-quality area scans are suited to solve the task. The high degree of redundancy is the key for the precise alignment of a sequence of overlapping patches. Advanced algorithms have been developed that allow continuous operation of the 360° scanning process. Real-time operator feedback guarantees a high-level of usability in a convenient medical device.

Multi-Scaling 3D Measurement of the Skin Face & Body #08

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Introduction: Anti-ageing & Skin care product or treatment are acting at different level of the skin producing some changes which can be measured on the surface at different scale level. Aesthetical and cosmetics treatment produce effects at very small scale on the skin from micron to millimetres and wish to market effects which are related to the eye perception and in this case the scale is more in the millimetre to meter range.

Objectives: The technology of 3D scanner improved in the past years to provide high resolution measurement on a larger scale. It becomes interesting to compare measurement which can measure locally to assess wrinkles, fine lines and skin texture while assessing as well the full face perception looking at most of wrinkles, fine lines & folds but also to shape and volume changes.

Methods: New generation of 3D scanner technology combine the well-known fringe projection technique with stereometry. This overcomes some limitation due to Fringe projection itself and others from stereometry itself. It is possible to use high resolution camera (up to 16 Mpixels) and project fine fringes without problems.

Associated with a dedicated positioning bench, the 3D scanner can capture in a few shots the complete face or body part, merging left and right side and start analysing all well know areas of ageing on this face or body. Powerful algorithms will align, merge and extract all these areas automatically and calculate depth,

length, volume, areas and more. New algorithm can also provide unique evaluation of fine lines, wrinkles and folds perception by given a density of these features on the face or body.

Results: Studies were conducted using different resolution of the scanner. Results will show that multiple areas on the face can be addressed from the same measurement while the sensitivity of the new algorithm over the age show a new way of assessing wrinkles, folds and fine lines. We will illustrate also the capability of this multi-Scaling scanner to address morphology changes on face and body parts like Leg, haunch etc..

Conclusions: MultiScaling 3D scanner open new possibilities to address local and global evaluation of the skin ageing sign on the face and body part. New algorithm also open ways of evaluating cosmetics efficacy, closer to perception. Sensitivity of these technologies is enough to see small changes, relevant from cosmetic effect.

TECHNICAL SESSION 2: BODY SCANNING FOR APPAREL I

3D Product Development for Loose-Fitting Garments Based on Parametric Human Models #38

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Researchers and commercial suppliers worldwide pursue the objective of achieving a more transparent garment construction process that is computationally linked to a virtual body, in order to save development costs over the long term. The current aim is not to transfer the complete pattern making step to a 3D design environment but to work out basic constructions in 3D that provide excellent fit due to their accurate construction and morphological pattern grading (automatic change of sizes in 3D) in respect of sizes and body types. After a computer-aided derivation of 2D pattern parts, these can be made available to the industry as a basis on which to create more fashionable variations.

Developing a 3D-Printed Obese Model for Assessing Fit of Wearable Smart Garments #54

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Clothing systems have been successfully used as a viable embedding media for several vital signals monitoring systems, making them smart garments. Two persistent issues with smart garments are improper fit and wearing discomfort. When collecting biometric data, precise sensor placement is extremely important, and when a garment is not comfortable, it risks not being used at all. Conventionally, fit is often assessed using fit models, either human subjects or static mannequins. Most companies determine fit model sizes that represent a median population, and the garments developed thus cannot be scaled directly to an obese body, which now represents a significant portion of the US population. In this study, fit models representing the obese population were selected from the CAESAR scan database for male and female and a male body form was additively manufactured using 3D printing technique. Digital scans of 185 obese male and 204 obese female from the CAESAR database were used to select the appropriate fit models. The bivariate distribution of chest and waist-front length measurements determined a representative subpopulation of 15 male cases and 14 female cases. Furthermore, sagittal cross section curvature analysis was performed on the cases to capture profile variations. Subsequently, the anthropometric distance variations among the cases for several key landmarks were measured to establish a range for sensor placement on the smart garment. From the 15 male cases, one subject was heuristically identified as the final fit model. The identified scan was preprocessed and torso region of the scan was extracted using the Polyworks V14 software. In order to make a life-like replication of the torso, two 3D printers were simultaneously used to print the model as 16 individual hollow slices. Subsequently, the slices were assembled together to produce the full scale obese-fit-model 3D form.

Fashion Design and Development Based on 3D Scanning Technology #14

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Fashion, known as the flow of soft sculpture, is the perfect combination of technology and art. Using the three key elements of styles, colors and materials, the three-dimensional shape of garment is formed eventually. The development of computer science, especially applying the 3D scanning technology to fashion design, has made intelligent modeling realized which is impossible of using traditional design methods. In this paper, our research would extend the design thinking and method through the approach of style modeling based on the new 3D technology, form a more reasonable garment structure, and guide the innovation of clothing production mode. With the improvement of the media and computer technology, there will be more innovative forms applied to the design and development of garment.

Apparel Fit Assessment Using Parametric Models #26

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Apparel fit is a concern not only to apparel manufacturers who endeavour to produce better fitting ready-to-wear apparel, but it is also crucial to apparel retailers, who strive to sell satisfactory apparel products to consumers, that fit well. Better fitting apparel will help increase sales and reduce returns of ill-fitting garments. Apparel fit is how well a garment conforms to the 3D of the human body. It mostly entailed appearance and comfort assessments that are highly subjective and led to the satisfaction of consumers with an apparel in a still position. In functional clothing, apparel fit also factors the ability to accommodate movement of the body. With most fashionable garments, fit can be categorized into three: tailored fit which is described as perfect fit, body con (tight) fit aimed at showing off the wearer's curves and oversize fit, for intentionally loose garments.

For the above described fit to be achieved, it corresponds to the amount of ease included during the pattern making and construction of the garment. For tailored fit, wearing ease is included; for body hugging or tight fitting garments, wearing and design ease are excluded, and for the oversize fit, design ease is included. Most conducted studies on garment fit are mainly on the tailored fit, where the apparel skims the contours of the body and is eased in all the right places to achieve a perfect fit .

Given the subjective nature of fit assessment, where expert panellists have been used to generate good data, attempts of objective assessments have been introduced through virtual fitting applications with colour indicators to show tight fitting areas of the garment that need alteration. Garment simulation enables designers, pattern makers and apparel manufacturers to present style decisions, test the fit of a garment in less time than actual sewing and share the results instantly, without expensive sewing and shipping costs. Virtual apparel fitting allows consumers to visualise how garments look like when worn without physically wearing them. Many pattern makers use 3D garment simulation to test their pattern blocks and while drafting the pattern, to ensure that the drape and general fit of the garment are correct.

Virtual fitting has also paved a way for increased e-shopping, a retailing option that has gained popularity in recent years. The available computer aided design and manufacturing software packages have different capabilities. Hence the use of the garment simulation software will be discussed in the pilot project done in South Africa. The purpose of the study was to explore the capability of the Optitex software package in assessing fit on parametric models. The pilot project was guided by the following objectives: to determine the ease of using the software package in assessing fit virtually, and to assess fit of simple styled skirts using different fabrics for the benefit of the apparel manufacturing and retailing sectors.

A Discussion to Presenting Texture Effects in Costume Designing in View of 3D Printing Technology #29

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The popularization and application of 3D printing technology, promote greatly the development of the apparel industry. But there are still some queries with the technology in the garment industry at the same time. Because of it's reproducible characteristics and can mass producing, most of people in this industry believe that the technology is lack of artistry. The printer can not replace the traditional handmade artistic creations and embroideries. However, like oil painting or computer graphics, the 3D printing technology is the carrier of art, it's artistry is no less than the handmade manufacture. This is a reflection ahead of it's time. Through the technicalinnovation, 3D printing technology can produce it's individuality, and also can solve the problems from the texture effects in costume and the limitations of color. The popularization of 3D digital printing already can implement the presence from different texture effects. Like the expressions of splash-ink, dizzy catch in ink and wash painting in Chinese wind of fashion design, the texture changes according to the profile. It often says in garment industry, "there is no texture you not produce, but the price." 3D printing technology will become the mainstream in costume designing by forming the clothing shape from the change of textures. In this paper, we chose the case analysis as the main researching method. Using the special case of Iris van Herpen, a costume designer from Netherlands, and the modern art creation theory, we compared the art language directions between the 3D printing and the traditional handmade techniques. We discussed the improvement of performance in 3D printing technology. We introduced mostly about the technology used for presenting texture effects in Chinese wind of fashion design and discovering the diversity of color. Today 3D printing redefined "arts and crafts". By the development and innovation of the technology, it would be a more practical means of artistic creation.

TECHNICAL SESSION 3: MEDICAL APPLICATIONS I

Categorizing the Morbidly Obese Body Shape and Estimating Body Appearance Outcome before Weight Loss Surgery Using 3D Anthropometric Data #10

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Background. Categorizing the physical shape of the morbidly obese has been an inexact science. Surgeons can readily identify extreme shapes such as “android” or “gynecoid” but will have various opinions as to the shape of the individual that presents between these two extremes. Yet the physical shape of the patient is often an indicator as to the potential difficulty of the pending surgery. Using linear, circumferential, volume and surface area data provided by scanning morbidly obese individuals, a set of mathematical equations has been developed that classifies their primary shape and their shape tendency. With some exceptions, it has been found that these shape indicators remain consistent throughout the massive weight loss experience. This finding, combined with longitudinal data collected by scanning, aggregating and de-identifying thousands of surgical weight loss individuals allows the capability to estimate body appearance outcome prior to actual weight loss surgery, thus providing a realistic motivational tool to the pre-operative surgical candidate.

Methods. 1000 bariatric surgery candidates were scanned using a commercial 3D scanning device. The body image produced was measured using embedded measurement tools. Measurements included linear, circumferential, volume and surface area information. Torso height was determined, as was the height of the maximum circumference of the torso. The mid-point height of the torso was also determined. Ratios were developed that used this information to create a Shape Descriptor Scale. The Shape Descriptor Scale defines the shape of the bariatric individual, as well as the tendency of their shape. Individuals were scanned periodically after surgery and their Shape Descriptors calculated. Circumferential measurement, surface area and volume changes were normalized to excess weight lost during the period between scans. Predictive models were developed based on the standard 75% excess weight loss expected in one year after bypass or sleeve weight loss surgery.

Results. Categorizing the morbidly obese shape numerically using this technique is repeatable and not subject to various opinion. Those classified as android have a tendency to be more difficult and lengthier surgeries. Most of the morbidly obese, with some exceptions, appear to have the same numerical shape descriptors even after massive weight loss. This allows the ability to create a realistic predictive model of how the morbidly obese individual would appear at various intervals along the weight loss curve and at the end of the expected excess weight loss.

Conclusion. The development of the Shape Descriptor Scale and associated algorithms were made possible by the insight gained from having surface area and volume data along with heights of certain measurements. This information was created by 3D booth scanning, and combined in such a way to not only determine the shape of the morbidly obese, but also to use these shape characteristics along with other multidimensional data provided by the scanner and the individual's weight at the time of the scan to develop statistically accurate predictive weight loss models.

Microsoft Kinect V2 Based Human Postural Deformities Assessment

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Early detection of postural deformities in children and adolescents has great social interest. Many today recognized methods for deformities screening (e.g. scoliosis) use invasive radiographic or expensive CT imaging. Development of user-friendly, home-based non-radiographic monitoring tool with automated diagnostic has great value not only in diagnostics but also in progress monitoring during physical therapy.

Our method is based on a 3D snapshot of a human body created with widespread Microsoft Kinect V2 sensor. Resulting mesh in 3D coordinate system is analysed to recognize skeleton position and determine the posture of the human body. A virtual skeleton model is placed inside the mesh and allowed to iteratively self-adjust its position and size according to surrounding mesh, resulting in final 3D coordinates of centres of each joint. Bone-axis are formed by connecting neighbouring joints inside skeleton, while posture-axes are formed by connecting important joints of the virtual skeleton (e.g. shoulder posture-axis is formed by connecting the joints of both shoulders). Finally, body deformations are quantitatively measured as angles of

each posture-axis in horizontal, frontal and lateral plane (e.g. in case of shoulder posture-axis) as well as angles between two or more specific bone-axis (e.g. in case of spine deformities).

Our system proposes to offer a complete postural deformities screening with quantitative measures, using inexpensive sensor.

3D Craniofacial Morphometric Analysis of Young Subjects with Marfan Syndrome: A Preliminary Report #52

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Marfan syndrome (MFS) is a rare autosomic dominant disease of connective tissues mostly due to mutations in the fibrillin 1 gene. Clinical manifestations of MFS include a variety of signs and symptoms, mainly affecting the heart, blood vessels, bones, joints and eyes, and comprising craniofacial alterations. At present, diagnosis of MFS is largely based on clinical signs and family history. However, it could be difficult, as its manifestations vary greatly and they are not always present right away. Since a life-threatening complication of MFS is aortic dissection, an early diagnosis of the disorder is essential. We aim to better describe the face of patients with MFS, identifying new quantitative morphological features which could facilitate the early diagnosis of the disease. In the current preliminary study, a group of young subjects with MFS was investigated. Three-dimensional facial images of 3 girls and 8 boys aged 5-15 years were collected by stereophotogrammetry. From the coordinates of 50 anatomical facial landmarks, linear distances and angles were measured; z score values were calculated through the comparison with data obtained from 556 control subjects matched for gender, age, and ethnicity. All subjects with MFS showed a longer face than controls, mainly due to an increased middle third (mean z score = 1.7). They also showed a longer mandibular body (mean z score = 1.4) with a shorter ramus (mean z score = -1.4) and a greater facial divergence (mean z score = 2.2). The assessment of facial features of subjects with MFS pointed out some morphometric characteristics that had never been reported in literature, alongside with other well known alterations, and suggests the usefulness of a three-dimensional quantitative approach for the recognition of facial phenotypic features of the syndrome. Nevertheless, they need to be confirmed extending the study on more patients.

Three-Dimensional Craniofacial Features of Glut1 Deficiency Syndrome Patients #53

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Glut1 deficiency syndrome is a neurological disease due to impaired glucose transport across blood brain barrier. The disease is consequence of mutations on gene SCL2A, encoding for protein GLUT1, which is responsible for glucose facilitated diffusion from intracellular to extracellular compartment. Mutations of this gene lead to a syndrome characterised by infantile seizures, developmental and cognitive delay, movement disorders, microcephaly and hypoglycorrhachia. Currently, the diagnosis of this condition is clinical and genetic, but the recognition of some craniofacial features typical of the patients, and easily observable during a routine medical evaluation, could be of great help for an early diagnosis. In order to characterise the phenotype of Glut1 deficiency syndrome (Glut1-DS) patients and improve the diagnosis of the disease, a three-dimensional assessment of soft tissue facial features was made using stereophotogrammetry. We studied 7 patients with Glut1-DS. The three-dimensional coordinates of a set of standardised landmarks, previously identified on the face and then digitized on the three-dimensional facial reconstructions, were collected and used to calculate anthropometric linear distances and angles. Z scores, obtained comparing patients with healthy reference subjects, matched for gender, age and ethnicity, were used for comparisons. Results showed that Glut1-DS patients have a set of common craniofacial features; most of the anomalies were found in the mandible. Glut1-DS patients seem to have a more anterior chin; their mandibular body is longer but the rami are shorter, with a reduced gonial angle. Data can be of great interest to improve the diagnosis of this syndrome and to allow longitudinal evaluations of facial morphology in a safe and not invasive way. Nevertheless further evaluation on a larger sample is advised.

TECHNICAL SESSION 4: BODY SCANNING SYSTEMS

From Handheld Tablets to Retail Booths - New 3D Body Scanning Solutions

David BRUNER

Size Stream LLC, Cary NC, USA

Size Stream outlines the company's 2016 product landscape for the full range of body scanning solutions from handheld 3D scanning to body scanning booths. These new products address the full spectrum of body scanning needs from "scanning at home" with a body scanning-capable tablet application to a new high end (but low cost) 3D retail booth body scanner in a record small footprint.

Market demand for low cost, portability, and even scanning at home, can now be satisfied with new devices and 3D scanning platforms on Windows 10 and Google Tango. The addition of 3D sensors along with traditional cameras enables a greater level of accuracy to meet broad market requirements such as size selection of clothing and body tracking for health and fitness.

Size Stream has leveraged its expertise in full body scanning to create a compelling mobile application that addresses shortcomings with single sensor scanning devices currently available. Key unique features are: Fast scan capture process; Fast processing to measurements; Fully private - calculation occurs on the local device; Accuracy competitive with home measurement and in-store retailer measures; No additional hardware required; Small space requirement (no need for room for the scan subject to spin around); Free App download for consumers and retailers!

A new 3D body scanning booth prototype that will be the technology basis for the Size Stream 2016 booth 3D scanner products is presented. The technology will showcase groundbreaking features, including: The smallest-ever footprint for a full body booth; Super fast 3D scan acquisition; More accurate 3D sensors; Twenty+ sensors to give total full body coverage; Higher resolution and higher quality color data.

The Body, as a Digital Platform for your Lifestyle

Raj SAREEN

Styku, Los Angeles CA, USA

Body scanning, at its core, presents unique value in delivering the first digital asset of your body. As a result, body scanners are finally reaching mass consumers through fitness and health. But why has it taken so long to reach acceptance? We will explore the evolution of body scanning in various markets. Following this story will help bring into focus the future of body scanning and the enormous value unlocked from its data.

TECHNICAL SESSION 5: BODY SCANNING FOR HEALTH, FITNESS & SPORT

Longitudinal Statistical Analysis of Weight, Volume, Surface Area and Circumferential Measurements for a Female Bariatric Population #09

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Background. It is generally well known that morbidly obese individuals undergoing a gastric bypass or sleeve procedure will lose 75% of their excess weight about 1 year after their surgical procedure. What is not known is the relationship, if any, between weight loss and physical changes to the individual's body shape and their measurements, including volume and surface area as they undergo this dramatic transition. A statistical analysis of longitudinal data from a de-identified and aggregated female bariatric population was performed that compared weight and anthropometric data collected from 3D booth scanners pre-operatively to such data collected post-operatively at 3, 6 and 12 months. Comparisons were made between weight loss, volume loss, surface area loss and circumferential measurement changes and a set of descriptive statistics was produced for each time interval.

Methods. Aggregated anthropometric data has been collected over the past seven years from sites that utilized various 3D booth scanners to document the physical dimensions of pre-operative bariatric patients, and to track changes to their physical measurements on a periodic basis after bariatric surgery. Data collected included weight, height and anthropometric information generated by a measurement extraction profile (MEP) applied to the pre-operative scan image and subsequent periodic scan image for each individual. This provided a multidimensional set of measurements that could be compared longitudinally to the weight recorded at each scan instance. For analysis purposes, a set of 100 female individuals were randomly selected from this collection of de-identified data. Averages and standard deviations were developed for each scan interval and a set of summary statistics comparing the preoperative weight and anthropometric data to the final, 12 month weight and anthropometric data was produced.

Results. After 3 months the female population lost an average of 50 pounds, torso volume of 15,200 cc and torso surface area of 878 sq. cm. However there was a wide standard deviation during this period. The average waist measurement reduced by 5.8 inches and the average hips measurement reduced by 5.9 inches. The waist/hips ratio was statistically unchanged, as were each subject's relative shape indicators. After 6 months standard deviations between volume and surface area and weight began to tighten, indicating a correlation with volume and surface area loss with excess weight loss. Finally, as the individuals began to tend toward 75% excess weight loss after a period of one year, volume loss and surface area loss began to converge with excess weight loss. Common circumferential measurements lost an average of 33% at the end of 1 year after surgical weight loss.

Conclusion. Massive weight loss after surgery results in significant changes in body appearance. Previous longitudinal monitoring consisted mainly of recording changes in weight and circumferential measurements. This doesn't tell the whole weight loss story. Multidimensional data provided by 3D body scanning allows monitoring changes to volume and surface area. The relationship between weight, excess weight loss, circumferential, linear and volume and surface area can now be simultaneously examined. This adds unique insight as to where weight loss is occurring as the body undergoes dramatic changes.

Whole-Body Magnetic Resonance Imaging Enables Assessing Spatial Accuracy and Precision of Skeletal Joint Locations Inferred from Motion Capture Systems #42

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Motion capture systems can be used to infer skeletal joints from three-dimensional surface information for various human poses. However, to-date it remains unclear how well the estimated joint coordinates coincide with the anatomically-correct joint positions. The aim of this study was to determine the localization accuracy and localization precision of inferred joint positions using Magnetic Resonance Imaging (MRI). Color and depth information (RGB-D), and skeletal information of an athlete in static pose standing upright were acquired. A whole-body 3D tomographic scan was also recorded using a 3T MRI scanner.

The deviation of the joint location was the largest for the left upper leg ($4.1\text{cm}\pm 0.2\text{cm}$) and the smallest for the lower arms ($0.2\text{cm}\pm 0.01\text{cm}$). The mean surface point distance averaged $2.2\text{cm}\pm 1.3\text{cm}$ (left upper leg), $1.8\text{cm}\pm 1.3\text{cm}$ (left lower arm), and $1.5\text{cm}\pm 1.0\text{cm}$ (right lower arm).

To our knowledge, this is the first attempt to use MRI as a gold standard to validate skeletal joint locations of a motion capture system. MRI provides a suitable means to validate skeletal joint localization for any motion capture system (markerless and marker based). However, advanced software solutions are required to validate and correct Kinect™ skeletal joint localization in the future.

Anthropometric based Estimation of adiposity - The ADEPS Project #39

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Worldwide, the prevalence of obesity has increased dramatically. Obesity is a condition associated with an increased amount of adipose tissue in the body and is linked to increased morbidity and mortality. In clinical practice and research, determination of body fat percentage (%BF) is not always possible due to limitations in available resources (time, equipment, budget, etc.). Therefore, weight indexes like the body mass index (BMI; $\text{body weight (kg)}/\text{body height}^2 \text{ (m)}$) offer a major advantage because they are quick and inexpensive to use. Although the BMI is extensively used, it does not take into account fat or muscle distribution in the body and is unable to differentiate adipose tissue from lean body mass. Hence, it has been suggested that future research in body composition measurement should focus more on body shape and volume rather than body mass. With the advent of 3D body scanning technology, it is possible to obtain accurate and reliable anthropometric measures of an individual within a few minutes. Also, 3D body scans provide information on an individual's body volume and body shape. From this data, %BF can be calculated using a two component model of the human body based on known densities of fat and fat-free mass. In addition, a 3D digital model of the body allows for visualization of regional fat deposition and division of the total body into segments for more detailed data analysis compared to total body measurements. The ADEPS project builds on experience with 3D body scanning gained during the SMARTFIT project and is looking to merge areas of expertise in

medicine, health care and technology. The principal aim of the ADEPS project is to examine the extent to which %BF can be predicted using anthropometric measurements obtained from 3D body scans using a structured white light full body scanner. A comprehensive dataset of anthropometric measurements obtained by 3D body scanning is available within the research unit. From these data, samples of candidate anthropometrical measurements will be selected using a Design of Experiments approach. Regression analysis on sequentially selected datasets will yield anthropometric predictors which will be used to create a predictive model for %BF as calculated from total body volume. This model will then be validated by comparing the anthropometric-based %BF predictions with %BF obtained from the Bod Pod® air-displacement plethysmography system (reference method and gold standard for total body volume measurement). Finally, the regression equation will be converted into a nomogram for routine practical use in healthcare and research practice. The present article describes the research project and its methods and reports on the progress and intermediate results of the ADEPS project.

Automatic Analysis of 3D Scans of Professional Athletes #44

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In this paper we present an analysis of body features of professional athletes performed using 3D body scanning with automatic processing and measurement of acquired 3D meshes and body composition data from dual-energy X-ray absorptiometry (DXA) acquisition. The aim of the work was to investigate whether professional male athletes practicing different sports show sport-specific features in terms of specific body dimensions and body composition. To perform the study, we collected 3D body scans and DXA scans of 211 players practicing basketball, soccer, golf, handball, rugby, volleyball as well as a control group of 38 physically active young adults.

A set of geometrical parameters were extracted automatically from the models exploiting a custom software tool based on body segmentation based curve skeleton analysis and symmetry based heuristics and previously applied with success to the analysis of body fat.

By measuring these body features from the scans, we could perform statistical analysis of their correlation with body composition parameters and also analyze differences among sports, in order to understand which features are more characterizing individual sports.

Furthermore, we checked if combinations of the selected feature measurements could possibly be characteristics of the disciplines and/or distinguish between professional athletes and physically active subjects, by visually analyzing the multidimensional feature space and testing automatic “athlete” or “discipline” labeling in a leave one out classification framework using different feature combinations and different classification methods. This allowed us to extract the most relevant features related to each different group.

TECHNICAL SESSION 6: BODY SCANNING FOR APPAREL II

Drape of Virtual Garments on Body Models: Impact of Mechanical Properties of the Fabrics #36

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Virtual garments are expected to break a fresh ground for textile and apparel industry. When flawless virtual garments on virtual models are achieved, this triumph will hopefully put an end to costly prototype production and pave the way for shopping apparel online without any concerns. OptiTex is a CAD program that enables fashion designers to create their patterns and garments in a 3D form. This program allows user to insert body measurements to obtain the virtual model. 3D scanned body images can be also exported to OptiTex to achieve garment simulations on realistic body shapes. Even though 3D scanned body models are identically with the real body shape, the simulated garments are not that realistic yet. One of the underlying reasons is that, allocation of the garment on the avatar depends on the drape of the garment which is strongly correlated to fabric's mechanical properties. Fabrics are non-linear, non-homogeneous, viscoelastic structures which makes them very complicated to identify. On the contrary to many other materials, fabrics are subjected to very low loads such as gravity, body motions, skin frictions and fabrics own internal frictions. In this research, bending rigidity, shear rigidity, extension, compression of three compositionally same woven fabrics (53% polyester/ 43% wool, 4% elastane; plain weave) are measured by Fabric Assurance by Simple Testing (FAST) system. Drape ratio is another important fabric parameter which gives information about the

formability of the fabric in real and virtual environment. "Cusick Drapemeter" is used to calculate drape ratio and number of drape nodes and amplitudes of the test fabrics. Finally real drape behaviors of these fabrics on a circular plate are compared with their virtual representations in OptiTex program in terms of drape ratios, node numbers and amplitudes. This study helps to understand how different fabrics drape on virtual avatars which can be provided from a 3D body scanner. At the end, the aim is to increase the interaction of garment and body model in virtual environment and obtain perfectly realistic representations of a virtual garment.

Volume Extraction from Body Scans for Bra Sizing #31

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We present a novel method for bra sizing based on surface scan data. While the current standard of finding the proper size for brassieres is based on only two 1-dimensional measurements, our approach takes the entire shape information into account. We propose to use the breast's volume as a good approximation for that shape. To compute the breast volume we introduce a robust and automatic algorithm based on measuring the volume difference of a torso with and without the breasts. Finally, we compare our novel sizing strategy to the traditional sizing of bras. We will show a better distribution across the population of test-subjects. Using the surface scan data in combination with our volume based sizing approach we can furthermore generate mean body shapes for every bra size which is of great benefit for bra development.

Determination of the Air Gap Thickness underneath the Garment for Lower Body Using 3D Body Scanning #20

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The heat and mass transfer between the human body and its surroundings is affected not only by the properties of the fabrics, but also by the shape and the thickness of the air layer between the garment and the human body due to the low conductivity of the stagnant air. Therefore, it is important to accurately determine the thickness of air layers between the body and the garment. The aim of this study was to accurately evaluate the change in the air gap thickness at the lower body for different garment fit (tight, regular and loose) and style (3/1 twill woven trousers and single jersey sweatpants). A standing stationary manikin, the highly accurate 3D body scanning and post-processing method developed in previous studies were used to determine the thickness of the air layers between the body and the garment. The results showed that the regional body sections had the strongest effect on the air layers beneath the garment. The garment fit had stronger effects on the air layers at the legs than the pelvis area due to body geometry and the garment style. This finding is useful for clothing modelling and design, and it implies that the modelling of air layers at the pelvis and the legs is possible, since the observed trends were unambiguous. The results of this study can contribute to an improved design of protective clothing and active sport garments. Furthermore, it will help to improve the simulations of the heat and mass transfer for lower body garments in various fit and design.

Conversion Technology of Clothing Patterns from 3D Modelling to 2D Templates Based on Individual Point-Cloud #15

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The research and application of clothing 3D technology focus on the 3D scanning data collection and analysis, the physical modelling based on the historical records, and the fitting and showing of virtual dynamics in China at present. In our research work of Three-dimensional Digital Studio, we will conduct a set of 3D scanning experiments between a body and a coating of the same object. Then we will make up a research chain of clothing patterns from 3D modelling to 2D templates based on individual, combining the usage of reverse engineering software to extract curves and surfaces of key parts. As an important result, we are going to offer an innovative research method to solve the study on the parameters relationship of space between human body and clothing, which will also offer a practical solution to the problems of 3D design and pattern flattening for loose clothing.

A Dense Surface Motion Capture System for Accurate Acquisition of Cloth Deformation #49

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In this paper, a system for dense surface capture of cloth deformation is presented. In the proposed pipeline cloth motion and dynamics are captured and reconstructed from a multi-view camera set-up. To allow precise tracking of a high number of surface points a tailored pattern is printed on the cloth. Several existing approaches make use of a printed pattern where point correspondence is determined using colour-coded vertex neighborhoods. In this paper we show that point correspondence can be improved and refined using a Laplacian mesh fitting process in the image domain. Results show an average increase of $\approx 20\%$ in the number of correctly labelled markers.

TECHNICAL SESSION 7: MEDICAL APPLICATIONS II

Palatal Volume Changes in Unilateral Cleft Lip and Palate Paediatric Patients #51

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Cleft lip and/or palate (CL/P) are the most common craniofacial abnormalities. CL/P therapy involves also orthopedic and surgical treatments. In particular, the orthopedic treatment can help to align the cleft segments and facilitate surgery. Traditionally, facial and palatal structures have been analyzed by 2D methods, omitting information of volume bone defects. A pre-surgical volume estimation can be useful to determine the anatomical boundaries of the alveolar bone defect; subsequently, volume assessments can appreciate the outcome of secondary alveolar bone grafting. In the present study, we developed a 3D stereophotogrammetric technique for volume estimation of the dental arches of children with CL/P. The method was employed to assess the 3D changes occurring in the maxillary arch of unilateral CLP (UCLP) patients with the use of plates before the first year of life. We collected 96 palatal casts of 32 neonatal patients with UCLP. Palatal casts were obtained before orthopedic treatment, before cheiloplasty, and after cheiloplasty. Half patients were treated with an active plate, half with a passive one. Casts were marked with a set of landmarks, digitized using a stereophotogrammetric system, and then analyzed. Volumes of the greater and the minor alveolar segments were separately assessed, and compared with a 3-w repeated measures ANOVA. Method accuracy was assessed using objects of known size, while repeatability was evaluated using Student's t test and technical error of measurements. Volume estimates were accurate, without systematic errors; random errors were lower than 5% of the total variance. Significant effects of alveolar segment and time were observed ($p < 0.0001$). Instead, no differences were found for the kind of plate. In conclusion, stereophotogrammetric systems can be a valid instrument to estimate palatal volumes of patients with CL/P during treatment, that can be followed up in a safe, rapid and non-invasive way.

High-Speed, High-Precision Scanner Ensemble Enabling 4D-Shape Analyses in Oro-Maxillofacial and Plastic Surgery

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New methodologies in medical analysis require dynamic 3D scanning with both, high-speed and high-precision. The paper presents an advanced solution for this challenging task. High-resolution is obtained by full-field phase shifting photogrammetry and DLP projection enables the high-speed implementation. Precise synchronization of multiple scan units has been realized for simultaneous capture without mutual interference. Comprehensive dynamic face scanning is achieved with 4 combined scan units. Examples of clinical application will be shown.

Low Cost 3D Scanners Along the Design of Lower Limb Prosthesis #25

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The evolution of 3D scanning systems has determined a large range of commercial solutions available on the market with different costs depending on their performances. The most interesting scanners for the sake of this research rely on structured light optical sensors like Microsoft Kinect v1 sensor, which are extremely

low-cost, but they still provide a precision that is valuable for some medical applications, e.g., the scanning of a residual limb.

In this research work, we present our CAD system based on a knowledge-guided approach to design the socket starting from two different 3D acquisition systems; the first one uses Microsoft Kinect and the second one exploits MRI volumes to get the final 3D shape of residual limb. Then, a comparison of introduced techniques to create 3D shape is exposed. Final outcomes are shown and discussed in the paper.

TECHNICAL SESSION 8: BODY SCANNING SYSTEMS II

The Potential for Multiple View Geometry in 3D Body Scanning Systems and Applications

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Visbody, Xi'an Saunier Electronic Technology Co. Ltd., Xi'an, China

Multiple view geometry is a computer vision problem to understand the structure of a real world object given several images of it, which is widely used in large-scale 3d reconstruction of historic buildings and geographic information.

Nowadays, This technology is applied in 3d body scanning because of some advantages of it. This presentation will give a brief introduction of multiple view geometry in 3D body scanning systems form several opensource solutions and show How this technology can benefit 3D body scanning systems and 3D body applications in the future.

Bodymetric Applications and Body Scanning by AICON 3D Systems

Dirk RIEKE-ZAPP

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AICON 3D Systems is one of the world's leading providers of optical close-range 3D measuring systems. The company, founded in 1990, develops and distributes systems for the business areas of inspection and testing including car safety and tube inspection. Since the acquisition of Breuckmann GmbH in August 2012, the product range also includes scanners for 3D measurement of complex geometries.

Based on a patented fringe projection technique, the 3D digitization and measuring systems are characterized by their extremely fast data acquisition time, together with a very high standard of adherence to detail, even when it comes most complex surface geometries. The scanning systems are predominantly found in the fields of technical and industrial engineering, but also in the context of human body measurements as well as arts and culture. Applications range from 3D measuring and digitizing up to quality inspection and reverse engineering.

Medical technology, cosmetics or virtual effects in the film industry - the methods of industrial 3D metrology are increasingly applied in the field of bodymetry and life science. Using the scanning systems for the contact-free, precise acquisition of teeth, skin structures, facial features or even entire bodies, you get sophisticated 3D scanning solutions for complex digitization tasks as: Reliable 3D data acquisition for the dental industry , Quality control of implants, Tracking of patient's movements, Scan data for documentation and efficiency studies at the highest precision , 3D digitization for science and forensics, True-to-detail replicas for product design and animation , Full body scanning for mini-me production as well as medical applications , OEM compoenents for special applications.

Unlocking the Body as a Digital Platform and the Rise of Reliable Consumer Scanners

William O'FARRELL

Body Labs Inc., New York, NY, USA

We live in a world where products and services are becoming more precise, connected and personalized. However, as businesses attempt to customize nearly every user experience, collecting accurate body shape, pose and motion data still remains time consuming and expensive. But over the course of the next year, with the emergence of commercialized 3D body scanners - alongside rapid advancements in 3D body modeling technology - businesses and consumers will finally be able to unlock the power of true product personalization on a global scale. Join Bill O'Farrell, co-founder and CEO of Body Labs, to understand how 3D body modeling technology will transform the way in which products and services are bought, sold and experienced.

TECHNICAL SESSION 9: DIGITAL ANTHROPOMETRY

Precise and Automatic Anthropometric Measurement Extraction Using Template Registration #19

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Anthropometric measures build the basis for many applications, such as custom clothing or biometric identity verification. Consequentially, the possibility to automatically extract them from human body scans is of high importance. In this paper we present a new approach based on landmarks and template registration. First, we propose a new method to define anthropometric measures once on a generic template using landmarks. After the initial definition the template can be registered against an individual body scan and the landmarks can be transferred to the scan using our second proposed algorithm. We apply our complete approach to real and synthetic human data and show that it outperforms the state-of-the-art for several measures.

Physical Evaluation of an Anthropometric Shape Model of the Human Scalp #23

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Former research has shown that statistical shape models of the human head can be deduced from MRI scans and that 100 models from a random selection suffices to predict any other head shape within the target population (Western adults between 20 and 40 years old). Representativeness was however only verified theoretically using repeated random sub-sampling validation, that is, with respect to other MRI scans from the same database [<http://www.loni.usc.edu/ICBM/>]. In order to verify the representativeness and accuracy of the statistical shape model for the target population, a study was performed to compare the actual scalp shape of 14 participants with their predicted scalp shape. In this study, all of the participants were measured in several ways and the prediction of the statistical shape model was compared to the actual 3D shape. Moreover, the accuracy of the prediction of an individual's head by the statistical shape model based on only four current and easy to measure anthropometric values was calculated. It was found that the statistical shape model's prediction of a real person's head scalp based on the anthropometric values: head length, head width, head circumference and the arc length over the width of the head, was accurate up to 2.12 mm where the theoretical verification obtained an accuracy of 1.6 mm.

3D Scan to Product Design: Methods, Techniques, and Cases #02

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3D scanning technology has derived great opportunities for ergonomic product designs. This paper is aimed to introduce various research cases and methods based on 3D scanning have conducted by an ergonomics laboratory in South Korea. Sizing systems and representative 3D models developed based on anthropometric measurements and 3D scan images with technical know-how were applied to the design of various products. Head, face, ear, upper limb, and waist parts, and full body in seated posture were anthropometrically analyzed for the design of headwear (e.g., helmet, goggle, and headphone), oxygen mask, earphone, arm-wear (e.g., watch, armband), hip protector, and vehicle seat, respectively. Customized software for the efficient analyses such as measurement of anthropometric dimensions, analysis of sizing systems, extraction of representative models, and virtual fit evaluation between products and the body were developed and applied in the product design process with massive 3D scan images. Representative models (e.g., torso and head) were printed in 3D for effective usage to the design and evaluation of related products. Advanced methods and techniques such as finite element modeling, morphing, and skin deformation have been applied to 3D scanned images for an advanced design of product shapes in further researches.

3D Ear Scanning Enables a Platform for Wearable Computing #68

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The ear and ear canal present exceptional challenges for 3D scanning technology. In addition to the typical challenges associated with scanning body parts (dynamic/moving components, large skin composition variability, etc.) the unique challenges of the ear and ear canal include the limited diameter of the canal, hair and wax interference, and sharp bends and undercuts in the shape of the canal itself. Although navigating

and acquiring data within this small skin covered cavity are challenging, the impact of such technology has large implications across a range of industries (medical, military, industrial, aerospace, music, and consumer electronics). Herein, we describe the design, calibration, use, and experimental results of a non-invasive, in ear, 3D scanning system (“eFit”). The eFit ear scanner allows for rapid, real-time modeling of the human ear - both the ear canal and outer ear. This technology has been validated across thousands of individuals with a volumetric scanning accuracy of better than 90 μm . The design and production of a custom in-ear product utilizing data from the eFit scanner is also described to further establish use cases of 3D ear scanning.

TECHNICAL SESSION 10: RGB-D SENSORS & LOW COST SYSTEMS

Body Scanning App: Data-Driven 3D Reconstruction and Applications #34

Alfredo BALLESTER, Eduardo PARRILLA, Julio A. VIVAS, Ana PIEROLA, Jordi URIEL, Sergio A. PUIGSERVER, Paola PIQUERAS, Francisco FOS, Marisol RODRIGUEZ, Juan C. GONZALEZ, Sandra ALEMANY

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The access to the 3D representation of people’s body shape has multiple applications to consumer goods which performance is related to human body dimensions or shape. This is the case of wearables such as clothing, footwear, headgear, orthotics, or equipment/environments such as furniture, transports or workstations. Some of the existing and potential applications of 3D human representations include personalisation, virtual try-on or size allocation for wearables or product configuration/adjustment for equipment/environments.

However, the cost of 3D scanners is high; the devices are too bulky for homes and retail stores; and its proper use requires expertise to get the relevant parameters from the 3D object (e.g. measurements). These three barriers are currently hindering the massive spreading of 3D scanners as consumer good or as typical in-store appliance.

This paper describes an array of approaches for realistically estimating human 3D shapes (i.e. full bodies or feet) using a regular smartphone or just entering a set of parameters (e.g. age, gender and self-taken measurements). The proposed approaches are based on data-driven 3D reconstructions, using parameterised shape spaces created from large 3D human body or feet databases. The algorithm finds the combination of shape parameters that best matches either the silhouettes extracted from the images or the body measurements entered.

Despite not being actual body scanners, these solutions are easy-to-use and can provide enough accuracy for applications such as virtual try-on, made-to-measure or size allocation of certain types of wearables. Moreover, they can be distributed to the final consumer or to the points of sale at a really reduced cost (or even for free), thus overcoming the main barriers to the massive spreading of its use in e-commerce, new retail experiences, new production pipelines or new business models.

In order to illustrate these technologies, some examples of application to different contexts (i.e. virtual worlds, e-commerce and personalisation) are presented: virtual try-on of female fashion (VisuaLook), size allocation for childrenswear (KIDSIZE), personalised comfort insoles (Sunfeet) and personalised shoes at the point of sale (InstantShoe).

Challenges of Designing a 3D Camera for Mobile Handsets and Tablets

Ian BLASCH

Alces Technology, Jackson, WY, USA

This presentation discusses the unique challenges of designing a 3d camera for mobile handsets and tablets. At Alces we have developed a unique structured light approach based on a MEMS projector. With this approach we are able to: 1. Build a light engine(projector) that fits into a 3mmx5mmx8mm volume (3mm is the stack height); 2. Provide per pixel depth information ; 3. Scale with XY resolution of image sensors; To remain low cost, must work with off-the-shelf image sensors ; 4. As depth calculations are per pixel, we are able to take advantage of vector processing – GPU trends; Must leverage on board ISPs and mobile processors ; 5. Work at any laser wavelength. We are demonstratig with 860nm, but can work with 940nm as well as any RGB wavelengths

ReconstructMe SDK: a C API for Real-time 3D Scanning #48

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Summary: ReconstructMe SDK2 is an ISO C library for performing real-time 3D reconstruction for hand-operated RGB-D camera devices. It provides interfaces for entire 3D scanning pipeline including pre and post processing steps, such as sensor data filtering and 3D surface post processing tasks. Developers can

embed ReconstructMe SDK in their applications, saving themselves the work of implementing their own scanning pipeline. To target a wide range of applications ReconstructMe SDK designed to scale simple single sensor applications to distributed multi-sensor frameworks with cloud based 3D reconstruction back-ends.

Availability: ReconstructMe SDK was first released in June 2013. Binaries, x86 and x64, are available for all common Windows platforms including mobile versions.

TECHNICAL SESSION 11: SCANNING METHODS & TECHNOLOGIES

High-Speed Accurate 3D Scanning of Human Motion Sequences #41

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In this work a new high-speed scanning technique based on pattern projection is introduced which allows acquiring human body 3D scans with a frame rate of up to 1.5 kHz. The measurement field and the resolution in the object space are variable. Thus one can either record whole-body scans with a resolution of 2 mm or highly resolved detailed resolutions (of e.g. certain muscle regions) of 300 μm . The 3D scanning methodology is based on fringe projection using a self-made projection unit and a recording using a high-speed stereo camera pair. Movements with velocities of approximately 40 km/h using the highest resolution can be resolved with high accuracy of the 3D data without disturbances by the setup. Hence, an analysis of locally restricted body parts can be performed, e.g. muscle vibrations as well as complex motion sequences, e.g. at certain forms of sport such as baseball, golf, or tennis.

Progress in the Adaptation of Shape-from-Shading to Human Body Shape Measurement #16

Harvey MITCHELL

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Shape-from-shading (SFS) is a process of determining an object's three-dimensional surface shape by using nothing more than the radiometric levels in an image of the object. SFS is feasible only with objects which have even optical texture and whose shapes are free from sharp curvature and discontinuities. Human body surfaces typically satisfy both these optical and physical texture requirements. SFS is also simple and cheap. Its major disadvantage is that, if only a single image of an object is used, it is impossible to quantify 3D shape variation using SFS – unless some approximations or assumptions are made. This paper is a report into an investigation which seeks to adapt single-image SFS to reliable human body shape measurement. An approximated mathematical model used to convert images to three-dimensional shapes aims to minimise the use of integration in the determination of surface shape. Since earlier reports on the project, the errors which occur in this process have been quantified. The paper outlines some theoretical concepts. The theory has been verified on simulated surfaces, and tested with real images of geometric shapes and real human body measurement. It is concluded that SFS techniques should be possible for the measurement of some body surfaces which have low levels of gradients and only a small degree of curvature.

3D Size-Estimation based on the Geodesic Distance Measured by Photogrammetric Scanning Device #12

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This paper introduces an innovative approach for estimating important body measurements according to the depth information extracted by photogrammetric scanning devices, such as Microsoft Kinect II, and verifies its applicability and efficiency through applying it to an experimental use-case concerning classification based on size, to be implemented in virtual fitting rooms. The mathematical framework consists, mainly, in constructing a projection from the screen coordinates associated with the pixels onto the real-world ones, and then integrating the geodesic distance gradients throughout a path connecting the beginning and end points. Besides, in order to reduce the inaccuracy through excluding the possible high-frequency noise, and to obtain more realistic measurements through minimizing the discrepancy between the original path and the one taken into account in the integration module, the path is fitted to a smooth curve in a separate stage before performing the geodesic-distance- calculation iterations. In the end, in order to verify the accuracy and preciseness of the proposed technique, it is applied for obtaining numerous body sizes, where for ensuring that the correct measurements are achieved, imaginary landmarks are placed on the bodies of the subjects. The results show that the accuracy is less than half a centimeter using Microsoft Kinect II.

Role of Background Subtraction in Creating Human Body Point Clouds from Photographs #30

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In this paper we research the influence of background subtraction on photogrammetry pipeline when creating 3D print ready human body data. Background subtraction is a technique in image processing where image background is removed from the image and only foreground is left for further processing. The goal of the paper is to assess whether background subtraction could influence positively or negatively the photogrammetric processing of photographs. The research is aimed at the freely available software that natively does not support background subtraction, but also does not forbid the use of background subtraction. We aim to find out whether the software could benefit from adding background subtraction algorithms into their processing pipelines.

Elasizer - A Low Cost 3D Space Measuring Elastic Tape for Everyone #35

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Elasizer, Kirov, Russia

The proposed solution is based on image recognition technology and geometry. The body 3D parameters may be extracted from 2D images.

To extract space body parameters, it is enough to put on a thin, highly stretchable elastic cover, on which, the surface is marked by non-stretchable geometrical objects to capture the image of the body. The size of each geometrical object and its position on the cover are known, which lets the computer system estimate the distance between the objects and build a virtual manikin of the body. The geometrical objects play two roles - as size etalons and markers. The combination of the single markers allows creation of a unique constellation of the markers, which transform the surface into a map or barcode, adding the ability to recognize the certain surface and body parts faster. Because of the markers, we are given the opportunity to use the technology in capturing body motion.

TECHNICAL SESSION 12: ANTHROPOMETRIC STUDIES & SURVEYS

3D Body Databases of the Spanish Population and its Application to the Apparel Industry #17

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Since the conduction of the CAESAR survey in the year 2000, more than 20 large-scale national or specific population surveys have been conducted across the world using 3D body scanning technologies of different kind. These surveys have been mainly addressed to the apparel industry and for some cases also for healthcare applications, most of the studies have been based on the use of a set of body measurements typically following ISO 8559 and ISO 7250 definitions.

In Spain, IBV conducted the Spanish female survey in 2007-2008 and has recently completed the male (2013-2014) and children surveys (2014-2015). The whole Spanish 3D database comprises over 12.000 individuals in standing posture sharing a common homologous structure and includes over 50 measurements by individual.

The recent standard EN 13402-3:2013 proposes to substitute the size codes of garment (e.g. XS, S, M, L, XL, etc. or 36, 38, 40, 42, 44, etc.) by the use of the body measurements that would fit the person wearing that garment. This document, currently under review, proposes the use of a pair of body measurements (i.e. one primary and one secondary) for the size designation and labelling of each type of garment (e.g. hips-waist for trousers, chest-neck for shirts, bust-hips for dresses, etc.). It also determines, for each primary and secondary pair of measurements, the intervals to be used for compiling standard garment sizes for men, women, boys, girls and infants based on the national anthropometric studies of different European countries (i.e. Netherlands, France, Sweden, Germany, Romania and Spain).

This paper describes the main results of the three Spanish surveys. And it also presents series of tools that will help the apparel manufacturers and retailers to make an effective use of Spanish databases in the design and labelling of products addressed to the Spanish market following the forthcoming size designation interval standards (EN 13402). These tools consist of a website providing with the basic anthropometric statistics, two books with the population measures by age range (one for female and one for male populations), a collection of digital mannequins and a collection of physical mini-mannequins (scale 1/20). Moreover, the access to the 3D databases makes possible to IBV to extend the use of these data for the provision of new consultancy services for clothing companies about how to improve garment design and fitting.

Development of an Anthropometric Database Representing the Singapore Population #45

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Anthropometric design is one of the most important disciplines within the area of ergonomic approaches. The objective of this study is to develop and establish an anthropometric database that represents the Singapore population. The database collected would be useful for other potential applications such as the local retail industry for apparels, shoes, vehicles and furniture; transport industry for the decision on cabin and seat sizes, and also many major and large corporations with large number of employees. More than 2000 Singapore citizens and Permanent Residents will be recruited from the public to take part in this survey. Age and gender will be sampled independently per age and gender group in a total of 5 age groups (16-20, 21-30, 31-40, 41-50 and 51-60). Racial/ethnic strata will not be controlled but will be reported as part of the biographical data. Body measurements are taken with a combination of traditional anthropometric tools and three-dimensional body and foot scanner. The subject's feet and hand are scanned using a Delcam iQube foot scanner. The subject's body is scanned in six postures using the VITUS Smart XXL 3D Body Scanner. In this paper, we will report some interesting findings arising from this anthropometric study on demographics, foot and shoe sizes and also the ergonomic study of chairs in two large lecture theatres and the seats of internal shuttle buses plying the campus.

Use of 3D Scanning Technologies to Extract Body Measurements for Customised Size Charts for Predominant African and Caucasian Body Shapes in South Africa #28

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The South African sizing system was adapted from an out-dated British sizing system. This contributes to the fit problems currently experienced by female apparel consumers in South Africa. To improve ready-to-wear apparel fit, body measurements and body shapes prevalent within a target population need to be identified and subsequently form a basis for a sizing system. The South African apparel industry bases apparel design and manufacturing on standard figures yet research shows that female consumer populations consist of women of different body shapes and body proportions. Diverse ethnic groups within populations further aggravate the variations. Differently shaped consumers experience different fit problems from standard apparel and size charts and therefore require differently shaped apparel. In an attempt to address ready-to-wear apparel fit problems among the ethnically diverse South African female population, this paper sought to compile customised size charts of body shape classes predominant among African and Caucasian women. This paper utilised scan data of 233 African (n₁ = 109) and Caucasian (n₂ = 125) women aged 18-25 years that were selected using the purposive and snow-balling techniques. Body shape descriptors from literature guided body shape classification formulae that were computed from circumferential drop values of the samples and mean \pm standard deviation. These were used to classify participants' bodies into different body shape categories. A print-out of virtual body images showing participants' front and side view images were subjected to visual analysis by a panel of experts to confirm body shapes assigned from measurements. The body shape defining parameters adopted in this study were. triangle: Mean to Maximum (in cm) i.e. $12.6 \leq \text{hip} - \text{bust} \leq 29.8$, hourglass: Mean $\leq \text{bust} - \text{waist} \leq \text{Maximum}$ i.e. $18 \leq \text{bust} - \text{waist} \leq 26.6$ and rectangle: Mean (18 cm) $- 3 \times \text{SD}$ (12.3 cm) $< \text{bust} - \text{waist} < \text{mean}$ i.e. $5.6 < \text{bust} - \text{waist} < 18$. Findings show that there were 64 African triangle, 42 Caucasian triangle, 30 African hourglass, 51 Caucasian hourglass, 14 African rectangle and 32 Caucasian rectangle. The significant differences between the Caucasian hourglass figure assumed to be similar to the Western hourglass used as a standard figure by ready-to-wear apparel manufacturing, confirmed need for customised size charts for the predominant body shapes among South African women.

This paper resulted in the computation of customised size charts for the different predominant African and Caucasian body shapes. While there are a number of Western studies that classify body shape using drop values, there has not been such study in South Africa.

SizeBR – Analysis of Brazilian Anthropometric Research #55

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Over those 10 years, according to the methodology was outlined and mature, the study of SENAI CETIQT went through several stages, from design and construction of projects preview, projects, testing preview, measurement and validation and final presentation of the project, the launch of SizeBR site, scheduled for

August 2015. Since when has acquired the tools for manual measurements and conducted feasibility studies with the sample group composed of students and staff of the institution itself, through technical shift logistics and equipment for measurements in all regions of Brazil. The entire project has as main purpose to meet with assertiveness best production of the textile and clothing chain. The measurement activities have occurred in the five Brazilian regions, including the Federal District, a total of sixteen states measured, within these were surveyed twenty-eight cities. Because of the breadth of Brazil, the research team also determined that the cities to be surveyed should be applied to the largest incidence of consumption. All research aims to answer more property Chain Textile and Apparel, with age distribution targeting Suggested indicators and region, and thereby guide the textile industrial producers and clothing manufacturers in developing products to meet the user. Consequently, the adoption of search enables the assertiveness in the design process, development and distribution of products generated by the value chain, increasing assertiveness in the construction of models and clothing gradations in relation to standards bodies. With the implemented methodology, one step higher towards the anthropometric characteristics of the pattern of the Brazilian body was possible, SizeBR project. Between 2012 and 2014, as shown below SENAI CETIQT listed the main consumption centers spread across five main regions: South, Southeast, West Cento, northeast and north to start the first anthropometric scientific study through scanning technology at the national level, in order to contemplate the large size of Brazil.

Currently SizeBR project team, SENAI CETIQT, dedicated to the end of the statistical treatment of the data obtained and, is expected to finalize and National Research presentation in August 2015 for males and females between 18 and 65 years. As concrete results the following bodies for females were defined: rectangle, triangle, spoon and hourglass (within the hourglass shape even find subdivisions of upper and lower hourglass). In men set up the bodies: athletic, normal, full, pronounced abdomen and burly. In the statistic it was developed a neural network that enables (with the inclusion of some key measures) a person check your position within the bodies of the database, thereby creating an avatar that shows all your measurements. This tool was created in order to facilitate e-commerce, since the person can locate your measurements in anthropometric tables, can associate them to the provisions of clothes available in the market. This generating neural network avatar tool will be available in our SizeBR site. Aiming also a greater range of research, the team of Innovation Management, Studies and Research through the behavior and SENAI CETIQT Consumption line also present the results of research on the Brazilian consumer habits that has been applied in conjunction with measurements from those regions. For each center of consumption, depending on the population served, applied to statistical theory of sampling to define the number of Brazilians to be measured (international standard ISO 15535: 2012). Thus a specialized team of experts in design, engineering, anthropology, social sciences, electronics and ergonomics has been trained to go into the field perform automatic measurements and manuals and treat the images obtained by body scanners.

TECHNICAL SESSION 13: BODY MODELING & AVATARS

Digital Cloning for an Increased Feeling of Presence in Collaborative Virtual Reality Environments #13

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Embodying an avatar in virtual reality (VR) experiences is very important to reach a high feeling of presence. This is even more important in a collaborative VR scenario where multiple users must interact to achieve a certain task. In this paper, we present a new VR platform combining 3D body scanning, motion capture and head mounted display allowing people to walk freely in a virtual environment, look at their own body, and interact with other users and physical objects. Instead of being represented by generic avatars, users can embody a digital clone of themselves obtained by a 3D scanner.

Evaluation of 3D Body Shape Predictions Based on Features #27

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The human body comes in many sizes and shapes. For design purposes, it is useful to be able to quickly simulate a virtual mannequin of a customer. A statistical shape model can be used for this purpose, because it describes the main variations of body shape inside the model's population. From this model, the specific features of each person in the population are known. Therefore, a mapping between the shape model parameters and specific features can be calculated, which allows adjusting the body shape, in an intuitive way. In this work, we have investigated how accurate a body shape can be predicted based on a set of features and which features are most suitable for this purpose. Height, weight, and hip circumference appeared to be the most suitable features to accurately predict the body shape.

A Markerless Method for Personalizing a Digital Human Model from a 3D Body Surface Scan #56

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Digital Human Models (DHM) are used for ergonomic design of products. For instance, vehicle ingress/egress motions are simulated for assessing vehicle accessibility. In order to validate simulations, experiments are often needed implying motion capture and motion reconstruction using a DHM. The first step for motion reconstruction is to create a personalized DHM respecting the anthropometric dimensions of the volunteer performing the task. However creating a personalized DHM from external body shape is not straight forward, because the internal skeleton has to be identified from external body shape. Here we propose a four-step method for generating a personalized DHM which matches a 3D scan. The first step is to clean the scan data and to prepare a DHM and a third body surface template. Then, thanks to the use of the third common body template, the correspondence between the DHM and scan surface points is established, making it possible to calculate the transformation parameters by kriging. From estimated position of joint centers, the internal skeleton is scaled and positioned from a known reference posture to the scan position. The third step is then to attach the surface points to their corresponding skeletal segments. The last step is to check and correct the attached skin points around some joints so as to respect the skin to segment structure specific to a DHM. Compared to the method used in the past by manually adjusting a DHM on calibrated photos of several points of views; the proposed method is operator independent and much less time consuming.

Human Body Reconstruction #18

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This paper gives a survey of different algorithms of human body reconstruction. According to different input data and devices we introduce human body reconstruction algorithms as two classes: image-based methods and depth data-based methods. The first class reconstructs the body with images, which is fast and convenient. However, it is not so accurate as the second one. Reconstruction methods based on 3D depth data differ in the processing of depth data. Some algorithms have accurate results by using total scanning data. Other algorithms estimate human model from part of depth data by using template or fitting in the database.

TECHNICAL SESSION 14: BODY SCANNING ASSESSMENT & USE

Lost in Translation? Coping with Multiple Scanner Vendors in a Commercial Environment #11

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Background. Changes in scanning technology and the emergence of additional scanner providers is, on whole, a healthy sign for the industry. It gives users of scanning technology the choice of vendors, and minimizes the possibilities of becoming captive to a particular scanner manufacturer. However, with choice comes challenges in integrating a new scanner vendor into the existing production scanner network. Each vendor has their own measurement software with specific capabilities and it is not reasonable to operate multiple software measurement platforms in a production environment. By using a data modeling program that accepts multiple 3D formats, one can convert the various vendor scanner outputs into a common file format. A data utility program then converts these files to a format to be measured and processed on a commercial basis. In all conversions there are distortions. Quantifying this distortion is not easy. The question is whether this distortion during the conversion process is significant.

Methods. Two scanners from two different manufacturers, TC2 and Sizestream have been utilized in a commercial scanning network, primarily for scanning morbidly obese individuals before and after weight loss surgery. The Sizestream scanner outputs its 3D scan in .obj format. The point density of this scan is often inadequate and needs to be subdivided using a data modeling program, which then converts this to a .wrl file format. This .wrl file is then further translated using a data converter utility into the TC2 binary file format. This binary file format is then loaded into the TC2 measurement software and converted to its proprietary .rbd format for measurement processing purposes. The equivalent measurements found in the measurement extraction profile used in the TC2 measurement program were programmed for the scans created by the Sizestream system using its measurement software. 50 de-identified morbidly obese individuals and their

common circumferential measurements provided by the Sizestream scanner measurement software were compared to the same group measured by the TC2 measurement software after the conversion process. Results. Chest, waist, hips measurements were relatively consistent between the two scanner manufacturers. The average differences were within .30 inches. Each software package had issues with finding the crotch point consistently and many scans needed to be manually adjusted. Once adjusted, thigh measurements had an average difference of .36 inches. Arm measurements from both software packages had issues determining the armpit and olecranon locations and were often times wildly inaccurate and inconsistent. These landmarks required manual adjustment. Even after manual adjustment, bicep and forearm measurements from the two software packages showed significant divergence.

Conclusions. At present, maintaining a high volume multiple vendor scanning network requires the use of a single measurement software package, and conversion from one scanner output format to a common measuring format using data conversion utilities. This eliminates measurement divergences between measurement software packages. There is some distortion due to data translation, but this can be minimized by careful manual landmark location. Regardless of the scanner used, arm landmark locations are often inconsistent. The resulting measurements are therefore estimations and best used for longitudinal measurement comparison rather than an accurate representation for a particular scan.

Validity and Repeatability of the Sizestream 3D Scanner and Poikos Modeling System #32

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Three-dimensional (3D) body scanning becomes increasingly important in the medical, ergonomical and apparel industry. The SizeStream 3D body scanner is a 3D body scanner in the shape of a fitting room that can generate a 3D copy of the human body in a few seconds. The Poikos modeling system generates a 3D image of a person using a front- and side photo. This study evaluates the repeatability and validity of both systems with human subjects.

Hundred fifty-six participants were included in this study, of whom 85 were scanned twice by the SizeStream Scanner and 139 by the Poikos modeling system. The repeatability is assessed by calculating the intra-class correlation coefficients (ICC) and standard error of measurement (SEM), and the validity of 6 Sizestream and 4 Poikos measurements is evaluated by comparing these measurements with collected tape measurements. The ICC and the SEM results indicate that 79 of the 163 SizeStream measurements are repeatable enough to use for fashion purposes, since they had an ICC above 0.80 and a SEM below 10mm. Fifty-one measurements give a good indication but are not accurate enough for pattern making. The waist, chest and hip circumferences are valid after a correction of the over- or underestimation of the measurements. The Poikos modeling system is a promising, but is as expected, less repeatable and valid than the SizeStream scanner. Although the Poikos modeling system can give a good estimation of the body shape, the measurements are not accurate enough (SEM > 10mm) to use in the fashion industry. Future studies have to be performed to validate more Poikos and SizeStream measurements and to assess the usability of these measurements for the fashion industry.

300 Body Scans in a Year: Data for Lifegraph Solutions #47

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A lifelong addiction to a multi-modal digital double that educates your parents, then you and your offspring, informs you of environmental factors and enables monetization of your life's plan, presence and past, in part or entirety, starts with 3D-body scanning. A vision for a LifeGraph (LG) product composed of a Human HealthGraph (HHG) built on the daily acquisition of a whole-body surface scan using a personalized body scaffold for a multi-modal sensor array with total-body field of view (FOV) is presented. Based on the history, state and trends in digital human modeling & simulation, motion capture and humanoid animation LG/HHG requirements are discussed. A summary of 300 body scans of the author from August 2014 to August 2015 is presented. A portfolio of projects to develop the LG/HHG product line for the prototypical 100-year human life is presented in the context of daily, if not, continuous education, measurement and monetization.

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