Working Group Progress For IEEE P3141 – *Standard for 3D Body Processing, 2019 -2020*

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Abstract

The 3D Body Processing Industry Connections (3DBP IC) group, an adjunct to IEEE P3141 Working Group (WG) is developing recommendations for 3D body processing interoperability to enable the exchange of 3D human body anthropometric related information across an ecosystem encompassing consumers to creators. Representatives from diverse industries aim to establish operating principles to aid in the transformation of the retail experience. This paper also updates the status of the IEEE P3141 Working Group, Standard for 3D Body Processing (3DBP) Working Group.

This paper summarizes the 3DBP activities conducted during the past year (Q4 2019 - 2020) and provides an overview of the topics to be addressed in 2021. During 2020, the working group published two white papers focused on the Comparative Analysis of Measurement Methods, Past, Present, and the Future of 3D Scanning, and 3D Foot Measurements Terminology.

Keywords: 3D Body Processing, Landmarks, Measurements, Anthropometry, 3D Scanning, File Formats, Metadata, Comparative Analysis, Footwear, Apparel, Communication, Security, and Privacy, Standards

Introduction

When one considers the challenges of digitizing a global population in a constant state of flux (movements and weight change), the long road toward apparel digitization becomes justified, if no less frustrating. Ultimately, the time burden of body surface scanning will be on the consumer (embedded in the cost of the goods) while the cost of data management for the useful life of those extensible 3D bodies scans will be on the supply chain. For the Fashion/ Retail industry to capture measurements and preferences will require 3D Body Standards to be developed and consumer's privacy concerns addressed.

Fiber, textile, fabric, and material specifications along with most fashion & footwear designs, and apparel patterns are becoming increasingly digitized Establishing the IEEE P3141 – Standard for 3D Body Processing is critical towards this effort and all other apparel digitization concerns, such as on-demand manufacturing, Made-To-Measure (MTM) products, increasing customer satisfaction, reducing garment returns and sustainability. The results can be combined with human body models to create digital files for AR/VR, apparel design and apparel design approvals.

The 3DBP IC group includes six subgroups to cover the broad scope and interdisciplinary nature of virtual fashion. The subgroups assess and reports on key performance parameters essential to the transformation. The goal is to increase consumer satisfaction (i.e. lower returns) through a predominately virtual experience while making recommendations for 3D body processing interoperability. The 3D body scans should be extensible in different contexts to allow for innovative solutions that protect the consumer while incentivizing the fashion industry to adopt the standard, such that 3D body scan data exchanges are accountable, transparent, secure, and possibly catalytic for Made-to-Measure (M2M) service offerings.

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3DBP Industry Connections Group Current Publications

In 2020, the 3DBP group will publish three white papers in addition to this overview paper. The white papers reflect the work of the IEEE P3141 WG subgroups. These papers will be made available on the IEEE 3D Body Processing website.

White paper: Comparative Analysis of Measurement Methods, Past, Present and Future of 3D Scanning [1]

In Q4 2020, the Quality subgroup will publish a white paper detailing the methods and results of the Comparative Analysis of Measurement Methods. The objective of the study was to gather anthropometric data on living humans using different technologies, namely traditional anthropometric methods (past), 3D scanners (present) and smartphone apps (future), to:

1. Assess the reliability and compatibility of body measurements extracted from full body scans.
2. Release examples of the outcome datasets, i.e. 3D scans and measurements, from the different technologies and make them publicly available.
3. Create data resources for the IEEE 3DBP initiative to develop and test 3D quality metrics

The de-identified data and models will be linked to the IEEE 3DBP IC website for usage.

White paper: IEEE 3D Body Processing Industry Connections (3DBP IC) 3D Foot Measurements Terminology [2].

In Q4 2020, the Footwear will publish a white paper on compiled footwear definitions from various sources for a comparison. This paper is a compilation of definitions from industry. The sources included ISO ISO/TS 19408:2015 [3], JIS S 5037:1998 [4], SATRA, I-ware, Volumental, IBV, TryFit, TechMed3D, Aetrex and BodyForm3D. The paper includes recommendations for defining foot measurements and methods, foot attire, and additional new measurements for better fitting footwear. The need for new measurements is derived from discussions are found in supporting references or industry professionals. Measurements that are required for certain types of footwear are also presented.

White paper: IEEE Functional Anatomy, Terms & Common Foot Conditions [5]

In Q4, a companion white paper will be published covering functional anatomy terms and concepts from a medical perspective. The paper is not to serve as a comprehensive review of all factors important in footwear design but will introduce functional anatomical and biomechanical terms and concepts along with a brief discussion of the most common foot conditions and their relevance to the health implications of footwear.

Technical Working Subgroups

The IEEE 3DBP IC constitutes six subgroups to cover the broad scope and interdisciplinary nature of virtual fashion. The subgroups assess and report on key performance parameters essential to the transformation. The goal is to increase consumer satisfaction (evidenced by lower returns) via the predominately virtual experience while making recommendations for 3D body processing interoperability.

The 3DBP is an umbrella technology working group with separate subgroups focused in the following six areas:

- File Formats (including Metadata)
- Quality
- Communication, Security and Privacy (CSP)
- Footwear
- Mega Technology Trends
- Fit

File Format Subgroup

The *File Format* subgroup worked with the Web3D group to better understand the meta data required for file formats beyond with 3D model alone. Topics included X3D/H-Anim standards which encompass extensible metadata for efficient and secure storage, archival, communications, and transforms (e.g., processing interactions of 3D model body with virtual garments). Furthermore, the *Open3D* library [6] is yet another consideration the subgroup is investigating and will work with the CSP subgroup in regards to how data is stored so that a balance between binary or formatted data is managed by the system; binary data is compact, but not portable. The challenge is efficiency in storage and communication, as formatted text data is portable, but not dense.

Quality Subgroup

The Quality subgroup is focused on developing preliminary methods, tools, benchmarks, resources, and testing procedures to define and quantify the quality of 3D models, as well as the quality of the critical metadata for use cases, such as body landmarks and measurements.

3D imaging has experienced rapid market growth since its development in the 1980's. There are now many types of 3D surface imaging systems - each using different hardware, software, computer vision techniques and landmarks resulting in differing measurement locations and degrees of accuracy and precision.

Whilst manufacturers and independent studies have evaluated systemic and random errors of particular 3D surface imaging systems, diverse factors such as population samples, landmarking, measurement definitions, data cleaning processes or analysis methods inhibit informed judgements between systems and against manually collected data.

The IEEE 3D Group completed a *Comparative Analysis of Measurement Methods* in Valencia, Spain in October 2019. Multiple retail partners compared the results of phone apps, booth scanners, and manual measurements in a controlled environment using the same subjects. The results from all phases of the study will be released in a white paper in 2020 along with the de-identified body scans for research purposes.

The aim of this study is to assess and compare the results obtained from different 3D body processing approaches (body scanners, smartphone apps and traditional anthropometry). The approaches will be quantitatively assessed for their ability to produce reliable and compatible results when conducted with consistent methodology. This will be the first study of its kind to evaluate eight different commercially available systems currently on the market.

Such investigations have been performed in the past. However, each of the studies used differing population samples, measurements (often because of differing landmarking or measurement definitions), data cleaning processes and analysis methods. Therefore, a clear and correct comparison between studies is not possible. Although protocols for evaluating the accuracy and repeatability of 3D body scanners hardware and software using test objects and human participants have been proposed, no protocol that accounts for multiple measurement methods; 3D surface imaging (system and app based) and manual measurement, has been proposed. This makes informed judgements about the accuracy and repeatability of these systems unsuitable.

The methodology presented here utilized widely available mathematical tools, including statistical models, minimum sample size, several estimators and plots appropriate to describe the data and quantify the repeatability and compatibility of the different measurement extraction methods. It uses commonly criteria to assess the statistics. In addition, the methodology obtains comparable snapshots from each digital technology to facilitate assessment by potential data consumers. See Figure 4 as an example of snapshots.

The study consisted of two phases: Phase One – Portland, Oregon (USA), December 2018 and Phase Two - Valencia (Spain), October 2019. A total of 133 subjects (61 in Phase 1 and 72 in Phase 2) participated in the study. All participants were selected to cover a wide range of body height and weight. Each subject had 11 body measurements collected twice by different measuring stations (3D scanning booth, smartphone apps and traditional anthropometry experts). Phase 1 included two 3D scanners - Vitus Bodyscan (Human Solutions GmbH) and SS20 (Size Stream LLC); and four experts. Phase 2 included two 3D scanners - MOVE4D (Instituto de Biomecánica) and Portal MX (Texel LLC); four smartphone apps -3D avatar body (Instituto de Biomecánica), SS@Home (Size Stream LLC), 3DLOOK (3DLOOK Inc.) and eM+ (PolyU); and two experts (Figure 1).

Figure 1: Measuring stations involved in Phase 2. [7]

Each subject was scanned and photographed twice with repositioning. This required a subject to enter and exit the scanning/photographing space for every repetition. Each subject was manually measured by each expert measurer twice. Because within-measurer and between-measurers needed to be independent and the independence guaranteed, the two measurement sessions took place at different times. The order in which subjects were measured was staggered, (i.e., different subjects were measured in between) and landmarks were remeasured and refreshed. Subjects wore tight-fitting clothes when measured in all measuring stations and used a swimming cap when the hair was a possible error source.

After the data was gathered, it was digitized and subjected to a first pass statistical analysis. This was done using an algorithm based on kernel density estimation (KDE) and z-scores. Thus, grossly inaccurate values were identified as outliers and, when there was no clear evidence of mistranscription, removed and declared missing.

Examples of the results are presented within figures 2, 3 and 4.

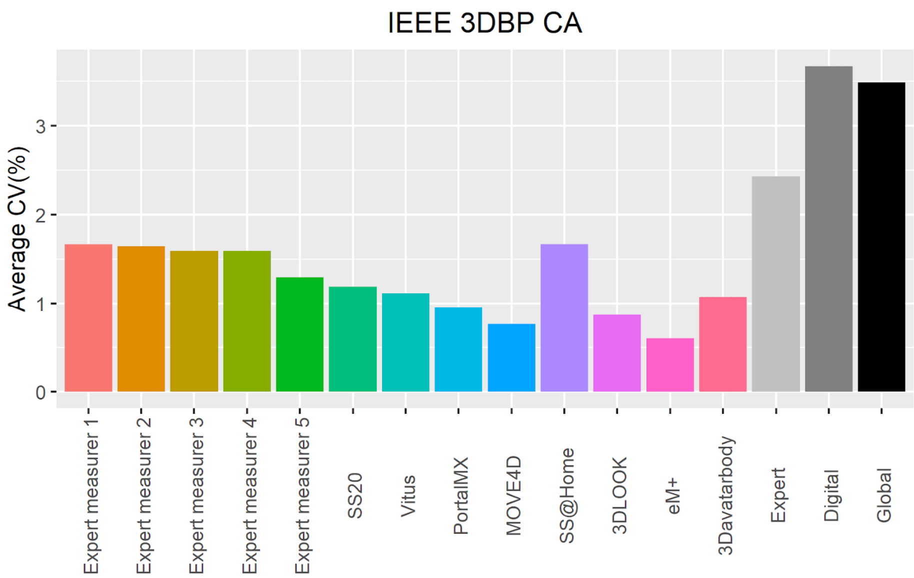

Figure 2: A Repeatability plot, using Global Coefficient of Variation (CV) for each measuring station. [8]

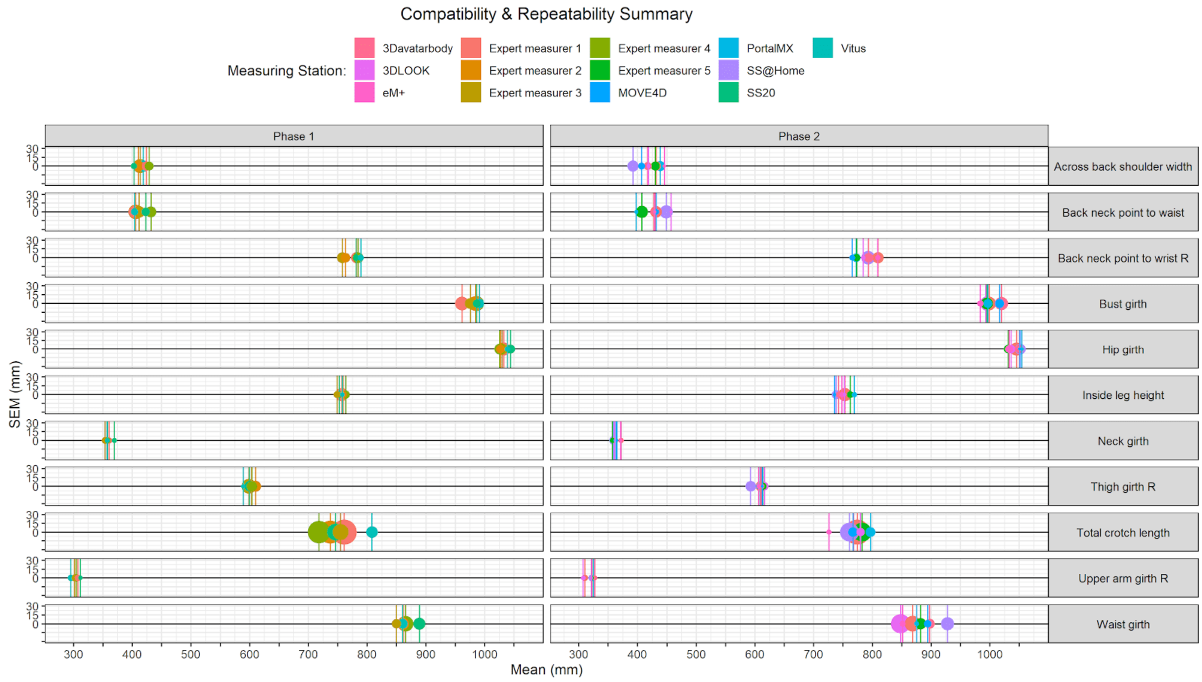

Figure 3: A Compatibility Plot, showing Bias and Standard Error of Measurement (SEM) for "Back neck point-to-waist" measurements. [9]

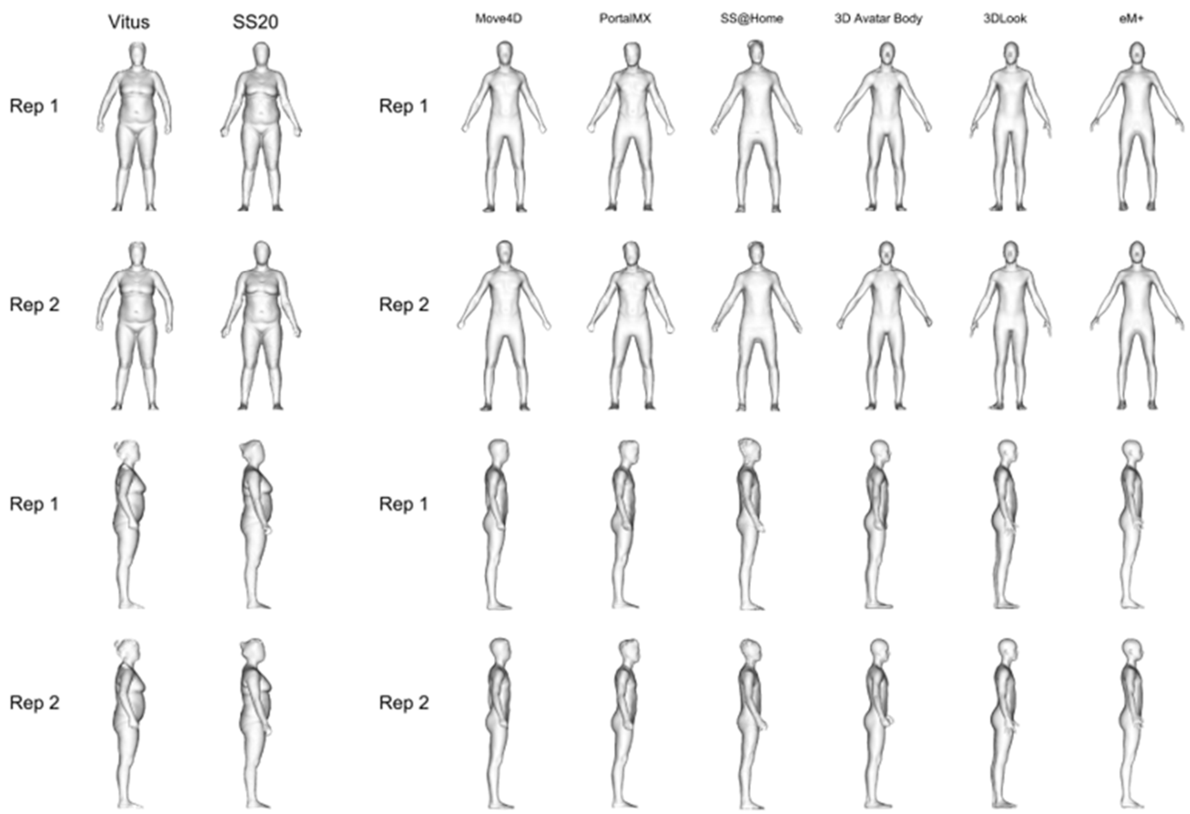

Figure 4: A qualitative assessment of 3D outcomes generated by different digital technologies from Phase 1 (left) and from Phase 2 (right). [10]

In summary, in terms of the two goals of this study

1. A powerful set of tools and procedures has been outlined for analyzing the repeatability and compatibility of anthropometric measuring systems.
2. A unique and excellent dataset of measurements and 3D scans has been gathered to compare anthropometric systems, both human and digital. The data shows that all individual measuring systems have high repeatability and accuracy. However, mixing measuring systems without adequate consideration causes severe degradation in performance.

Over the next year the subgroup intends to:

- Incorporate the lessons from the global studies into the work of the IEEE P3141 Standard for 3D Body Processing
- Use the tools and results of this study to help other IEEE 3DBP groups.

Furthermore, the subgroup intends to address cross processing.

- Each measurement is a combination of an acquisition technology, a reconstruction technology, and a measurement technology. It is often hard to completely decouple the acquisition and reconstruction technologies. However, it is often possible to de-link the measurement technology from the pipeline. (Sometimes another reconstruction or cleaning step is needed.) Cross processing is where all scans from all digital measuring stations are processed through the same measuring technology. This can be done for many measuring technologies and will serve to detangle the acquisition performance from the measurement performance. This may lead to insights into what combination of acquisition and measurement technologies perform best.

Communication, Security and Privacy (CSP) Subgroup

The *Communications, Security and Privacy* (*CSP)* subgroup is proactively engaged with IEEE and other Standard Development Organizations (SDOs), as well as industry consortiums and international standard organizations, to fully leverage existing standards, guidelines, and operating procedures, relative to P3141 CSP, with the intent to use industry practices and technology as part of the P3141 ecosystems.

The illustration (Figure 5) shows a *3D scanner* connected into a network using a wireless connectivity. In this illustration, Ethernet is used as a representative example of connected devices (printer, workstation, laptop, etc.), along with a 3D scanner. Existing standards may be used to describe the communication, security, and privacy requirements in this archetypal example, so the intent is to describe how a 3D scanner connects into a P3141 ecosystem.

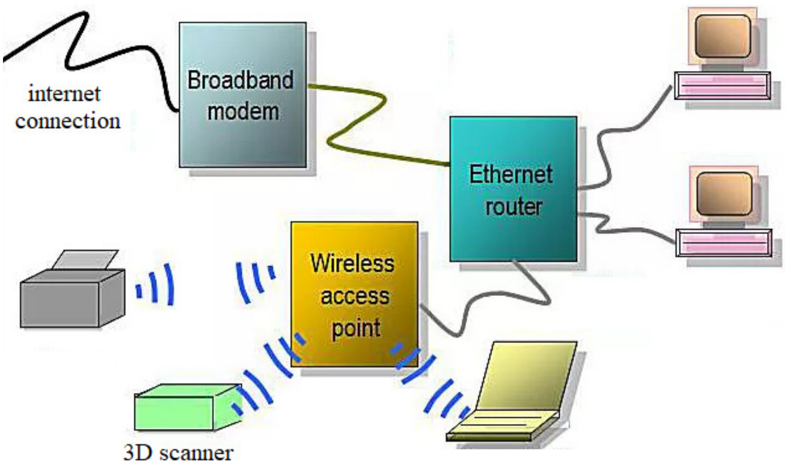

Figure 5. Representative illustration of connected devices [11]

If the 3D scanner is connected into the above illustrative network, the communications may need to be compliant with 802.11ax (High Efficiency Wi-Fi specification standard) [12]. Within the 3D scanner, there may be static and dynamic memory, a CPU or other controller, i.e., many of the components in a typical workstation. Within the 3D scanner, there will be a communication protocol to enable functionality of the 3D scanning system, so P3141 is primarily focused on exploring the system interface (i.e., Wi-Fi standards such as 802.3 [13], 802.11 [14], 802.15 [15], and wireless broadband standards such as 4G LTE [16], etc.). The current road map envisioned by the working group would allow the 3D scanner system to connect (communication) via an existing standard. The CSP subgroup recently commenced a closer examination of the appropriate requirements of the 3D scanner system. That is, if personally identifiable information (PII) is stored in static or dynamic memory of the system, shall this information be encrypted? If PII is contained in a file that an individual can download for personal use, how shall this information be protected, or is this outside the scope of the P3141 standard? Is it necessary to require the 3D scanner system be disconnected from any network when not in use to prevent intentional or unintentional PII exposure? The CSP subgroup is also considering PII from an Electromagnetic Interference/ Electromagnetic Capability (EMI/EMC) perspective to help ensure users or consumers trust in the system, relative to PII.

With distributed computing and multi-agent systems, consensus algorithms assume that some processes and systems will be unavailable and that there will be some loss in communications, so a more fault tolerant, consensus algorithm may be a building block for distributed 3D scanning systems to interoperate. The implementation of obfuscation to mask the true state values by adding noise on the state is one possible solution for the 3DBP and working group to further investigate as a viable solution for 3D scanners in terms of security and privacy. Specific to 3D scanners, blockchain consensus algorithms (BCCA) may be an approach for CSP, as BCCA ensures that each new block added to the network is the only version of the truth, which is agreed by all the nodes in a decentralized ledger scenario.

Blockchain is a distributed, decentralized network that aims to give immutability and security of data; each data transaction of a 3D scanner in a Blockchain network is considered truly secure and validated.

As the working group and 3DBP efforts move forward with CSP matters, it appears the benefits of encryption to preserve privacy and security may outweigh computational complexity and may more effectively manage PII in CSP.

Footwear Subgroup

The *Footwear* subgroup collaborated on a white paper identifying the inconsistent definitions of foot landmarks and measurements. In addition, a companion paper relating to foot anatomy and foot conditions that may impact footwear fit will be released in 2020.

The recommendation from the IEEE 3D Body Processing (3DBP) Industry Connections (IC) Footwear Subgroup is that the industry should make their definitions and measurement methods publicly available.

There are two main reasons for the industry to make their definitions known:

- If a brand would like to use more than one input device (scanner or phone app), they need to understand which definitions were used to determine those measurements and the measuring techniques used to get them. Otherwise, the difference in the values between multiple input technologies is not understood.
- If a brand is tying their process to a particular input technology, the process used to obtain those measurements by that input technology need to be understood.

The paper includes recommendations for defining foot measurements and methods, and foot attire. As noted previously, the sources included ISO/TS 19408:2015 [3], JIS S 5037:1998 [4], SATRA, I-ware, Volumental, IBV, TryFit, TechMed3D, Aetrex and BodyForm3D. Definitions are summarized for easier comparison.

As common foot aliments impact the comfort and fit of footwear, a companion paper was determined to be needed to help bridge the gap of knowledge between the footwear and medical industries.

A future companion paper of additional proposed measurements is planned to be published. The need for the proposed measurements is derived from discussions that were found in supporting references or industry professionals for better fitting footwear. Measurements that are required for certain types of footwear will also be presented.

Due to travel restrictions of 2020, a comparison of the foot scanners was not conducted in Europe in 2020.

Mega Technology Trends

The *Mega Technology* (MT) subgroup continues to evaluate various aspects of big data, AR/ VR, global Internet of Things (IoT), global Internet of Bodies (IoB), edge computing, blockchain technology, artificial intelligence (AI), high performance computing (HPC) and quantum computing; considering the potential opportunities that may further enable 3D human body scanning applications. Technology continues to evolve, and with this change comes new applications that are being adopted in a much timelier fashion. The MT subgroup has already realized that open and involved discussion regarding the impact of technology and how the drive for development will affect the continued deployment of 3D body scanning technologies.

The digital twin may be one of the most intriguing technologies that is bringing disruption to various sectors, including the apparel, energy, automotive, military and aerospace sectors. Digital twin technologies are impacting the planning, design and development, and operations workspace, and transforming the logistics sector. *MarketWatch* [17] recently published a report indicating the “digital twin technology market” was more than USD $3.3B with a potential compound annual growth rate (CAGR) of nearly 33% through 2026.

AI and specifically machine learning (ML), is driving development in many fields, and the use of simple and efficient programming languages may accelerate the applications that further enable 3D scanning.

There are many technology trends that will impact or influence 3D scanning. Part of the opportunity will be defining these technologies relative to P3141 and determining how these technologies may be best deployed in 3D body processing. The MT subgroup will attempt to systematically delineate the technologies and provide a road map of potential impact on 3D scanning, and how these technologies may be operationalized.

Fit Subgroup

The *Fit* subgroup’s mandate is to improve our understanding of how the fit of the 3D body and clothing (including wearable technologies) is assessed, and to guide industry processes to use 3D body processing to develop and deliver apparel that fits well. The group will consider ways to acquire and communicate fit data for digital product creation and improved consumer experiences.

Acknowledging the frequently lamented disconnect between garment fit and physical workflows, the group began with the focus of clearly identifying the issues behind this complaint. The group’s initial focus was to define terminology for precise communication of the attributes of fit, and to develop specifications that may be used to evaluate fit using 3D body models. Discussion surrounding this topic led to an analysis of manufacturing workflows, particularly regarding how garment dimensions were derived culminating in the production garment patterns. The debate, while not conclusive, lead to valuable insights regarding pattern-making workflows and where opportunities for gaining or losing control of quantified fit exist.

P3141 Standards

The *P3141 Standard for 3D Body Processing (3DBP) Working Group* formally commenced work in early 2020 and will leverage the 3DBPIC key opportunities as informative and normative clauses to enable interoperability, transparency, and broad market acceptance. The intent of the 3DBP WG is to more efficiently address the fundamental attributes that contribute to the 3D body processing and related metrics of those attributes and have identified subtasks and specific activities to further enable 3D body processing.

Conclusions

The vision and goal of the 3DBP initiative is to create complementary standards and practices that further promote an ecosystem that “lifts all boats” and drives future growth opportunities for players across the 3D body processing value chain. The focus for 2020 was to bring knowledge and methodologies to the 3DBP community via white papers and expanded outreach.

Collaboration with other standards committees and organizations is integral to the goals of this committee, and industry participation is critical to ensure current and future standardization needs of this expanding industry are addressed. Interested parties are invited to contact IEEE 3DBP for further information, https://standards.ieee.org/industry-connections/3d/bodyprocessing.html

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