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IEEE Industry Connections (IEEE-IC) 3D Body Processing (3DBP) Initiative– An Introduction

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IEEE Industry Connections (IEEE-IC) 3D Body Processing (3DBP) Initiative– An Introduction

Abstract

The background, goals, and status for the IEEE 3D body processing (3DBP) initiative are introduced in this white paper. This initiative was launched in the first quarter of 2016 with an initial focus on exploring technology standardization opportunities for hardware and software technologies across the “3D body processing” pipeline; i.e., from scanning of people and creating body model data to simulating, modeling, analytics, and visualization. A Virtual Fit use case and relevant 3DBP attributes are examined as an example of a 3D body processing use case. File formats, metadata, and communication protocols are discussed and initial guidance is proposed for evaluating and selecting among existing formats and protocols. While the white paper utilizes examples from an apparel/retail context, it is important to note that the direction taken by the 3DBP initiative is applicable to use cases in other industries such as health, wellness, fitness and athletics as well as complementary to adjacent technology ecosystems such as IOT, 5G, AI, fog, and cloud computing.

1. Introduction

For the past two decades, 3D scanning and modeling of the human body or body parts have been applied in various applications and industries. Today, we believe that 3D body-model processing hardware and software technologies are at an inflection point; i.e., the potential for mass adoption in industries such as apparel design, manufacturing, and retail are conditioned on not just total cost of ownership but on scalability, interoperability, and quality of experience as well.

Initially, creating a 3D body model mandated the use of relatively expensive and large full-body scanners. Advances made in the past few years in depth sensing technologies have made it possible to create 3D scanners models on PCs, tablets, and smart-phones at 100−250 times lower the cost. As such, a good number of start-ups, as well as established companies, are investing efforts in generating solutions that will allow people to create 3D body models of themselves at a fraction of the previous price and from the comfort of their homes. Scanning booths at points of sale are another option for model creation—an option that is being pursued by many companies.

Two important implications from the above trends are as follows:

- As the number of players increases, each often creating different types of 3D body-model data, so then does the risk of fragmentation and incompatibility across offerings.
- As incompatibility and fragmentation increases, the more challenging it will be for consumer-facing players (such as retailers) to scale solutions that deliver on intended quality of experiences.

Companies are already working on applications that will take advantage of the availability of 3D body models to provide previously infeasible benefits to customers. Specifically, this is taking place in the online apparel market.

While the online sale of clothing is increasing year after year at a faster rate than the overall increase in market size (17.5% vs 6% [1]), it is still only a fraction of the overall apparel world market (5% in 2015 [1]). One of the main roadblocks to increase online sales is the fact that people find it hard to figure out whether a clothing item they see online will satisfy them, both in terms of correct size and in terms of fit ("how would I look in this garment?").

As a result of the inability to sufficiently predict the fit, online sales businesses experience the following consumer behaviors that impact their bottom line:

- Large percentage of returns (25−50% [2], [3], [4])
- Customers ordering a number of items, in cadenced sizes, with the implicit intent to keep only one of them

For example, a 2015 study by IHL indicates a loss of approximately $62B to retailers from "buying the wrong size"[6]. Additional examples of these consumer behaviors can be found in [5] and [7].

Since the overall apparel market value is estimated at $1.5 trillion a year [1], it is clear that any change that brings even a small increase in online sales or a small decrease in returns will have a large, positive impact for the involved businesses.

The industry is looking at Virtual Fitting (VF) to increase online sales and unlock a set of business models, related to mass customization and made-to-order production. VF means that a person can select a garment in an online shop and get an on-screen, photo-realistic view of how the garment would fit him/her. The VF software must have access to a 3D body model of the online shopper for a high-quality VF experience. It must have access to digitized data of the garment. It can then drape the selected garment over the 3D model to create the VF experience.

Online solutions for size-estimation and size-recommendation software exist today. Some are linked with online sales sites. Some offer a level of fit estimation. While a step in the right direction, these implementations do not yet offer a full VF experience.

Making use of these models by multiple virtual fit experience providers calls for some standardization in the way the models are stored and shared.

Moreover, each of these implementations is a fully proprietary solution. They are based on large databases of clothing size, pattern, and fabric attributes information. They either get access to manufacturer's digitized clothes data or create it themselves. This work in "silos" limits the expansion of this section of the industry. Only a small number of applications make use of 3D body models; when they do, the application flow includes model capturing and generation, making it even more proprietary.

With more people getting access to 3D body-model generation equipment, we foresee an increase in the availability of these models. However, making use of these models by multiple virtual fit experience providers calls for some standardization in the way the models are stored and shared. Such standardization will improve the ability of different software vendors to interoperate across the cloud—exchanging information without the need for a lengthy integration process. We believe that the ability to interoperate in a non-proprietary environment will widen the market for use cases that are based on 3D body-model processing.

The 3D Body Processing (3DBP) IEEE Industry Connection group was launched to explore and address the needs described above. This white paper aims to serve as an introduction to current topics and direction around opportunities for standardization as well as to invite feedback from the global community of subject matter experts.

The structure of this white paper is as follows:

- Section 2: Provides a more detailed description of the need for interoperability and of relevant aspects on top of the model itself. This is done via a detailed description of a possible Virtual Fit example.
- Section 3: Discusses possible 3DBP use cases and the attributes that are relevant to these use cases.
- Section 4: Outlines four vectors where standardization can help improve interoperability: File format, communication (network protocol, security), metadata, and quality. Each of the vectors is explained. Guidelines for selecting standardization direction are suggested.
- Section 5: Summarizes the information in this paper and gives a short description of the content of the associated white paper.

2. 3DBP interoperability model

Figure 1: represents the high-level 3D body-model processing stages used as a baseline to explore and evaluate where standardization might create the highest shared value.

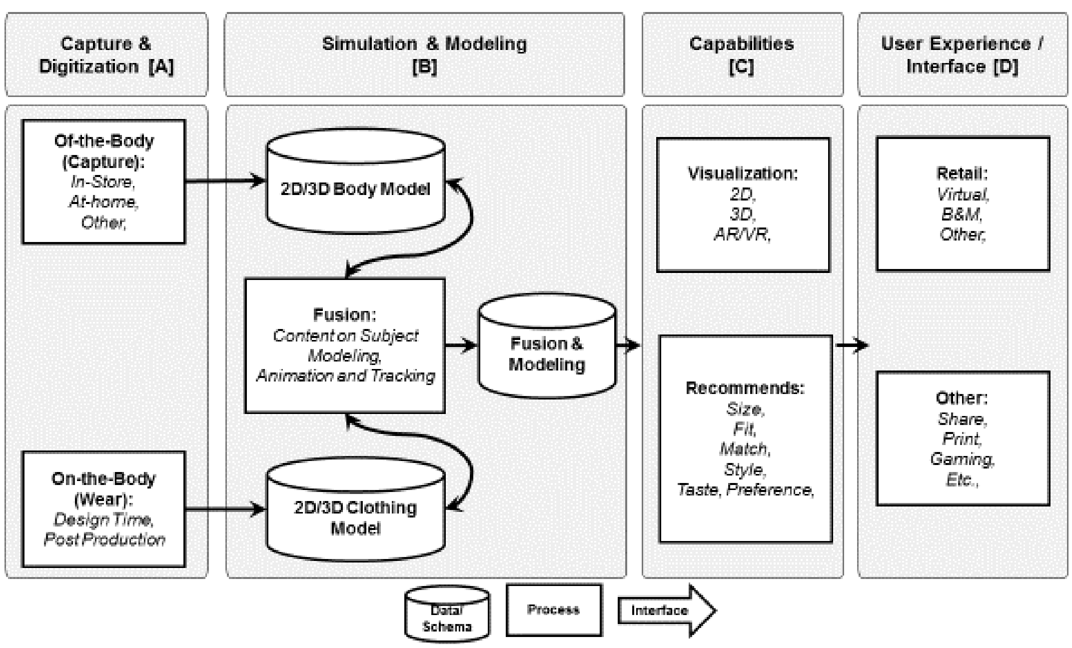

Figure 1: High-level 3D body-model processing stages

In short, the stages describe the general building blocks used to deliver any use case and are summarized as follows:

[A] Capture and digitization

- Of the Body—sensing and capturing of humans and body
- On the Body—sensing and capturing and/or digitization of body wear/items

[B] Simulation and modeling – creating body models, fusing, and modeling
[C] Capabilities—analyzing, recommending, and visualizing
[D] User experience/interface—interacting and sharing with people, systems, or applications

Using the building blocks, a generic flow of a typical 3DBP solution would be as follows:

- Scanning [A]
- Model generation [B]
- Landmarks and measurements elicitation [B]
- Digitization of objects (e.g., clothing, furniture) [A]
- Aggregation of data from various sources [B]
- Processing and integration of the data [C]
- Output the results [D]

An application may contain all or some of the above building blocks.

In what follows, we describe each of these steps by relating it to the Virtual Fit use case.

1. Scanning creates raw 3D point cloud. The point cloud includes noise, missing information (e.g., under the armpits), and may be piecemeal as a result of breaking data accumulation into several steps (such as scanning the subject a number of times to get the front, sides, and back data).

   In some cases, no point cloud is generated. Images are captured and in step 2 converted directly to a 3D mesh.

2. After the point cloud is generated, a variety of algorithms (public or proprietary) are used to generate a 3D body model mesh. Processing includes smoothing the data, stitching it (if there are a number of raw point cloud files), and estimating missing information. Some implementations fit the data to statistical models when generating the final model.

3. Once a model is available, it can be an input into software that estimates the location of landmarks and body measurements. This software is not necessarily tightly coupled to the model generation step and can run on body models regardless of the scanner used to create them. Some restrictions may apply. For example, the code may be expecting the subject to be scanned in a certain pose. Recognition and isolation of body parts may take place in this step as well.

4. Additional processing is required to produce a useful product. For example, digitized clothing can be virtually fitted over the body model. Digitized clothing provides attributes for cut, size, color, texture, stretching, and other attributes. The sources for this data can be local databases or remote repositories maintained by other companies (e.g., fabric manufacturers for fabric attributes; clothing manufacturers for clothes cut and size charts). Further aggregation may include downloading the body model itself from a model-repository (using some credentials to ensure the correct body model is

fetched); downloading a model of a garment; and downloading fabric attributes. An aggregating engine collects this data and provides it to the processing and integration step.

5. In the processing and integration stage, all the data is combined to create an end-user experience. For example, the end result can be a photo-realistic draping of a pair of trousers on a given body model.
6. The last stage provides the results in a relevant format. The results can be displayed on a screen and written to a database.

Figure 2: shows a possible split of the various stages. Note that in this figure, step 1, step 2, and step 3 are assumed to be completed by the same vendor. Aggregating the data is done in more than one place—fetching the body model and making the clothes selection is done by the online store software; obtaining clothing and fabric data is done by a processing entity that provides this service to the online store. The online store web application then displays the end result to the user.

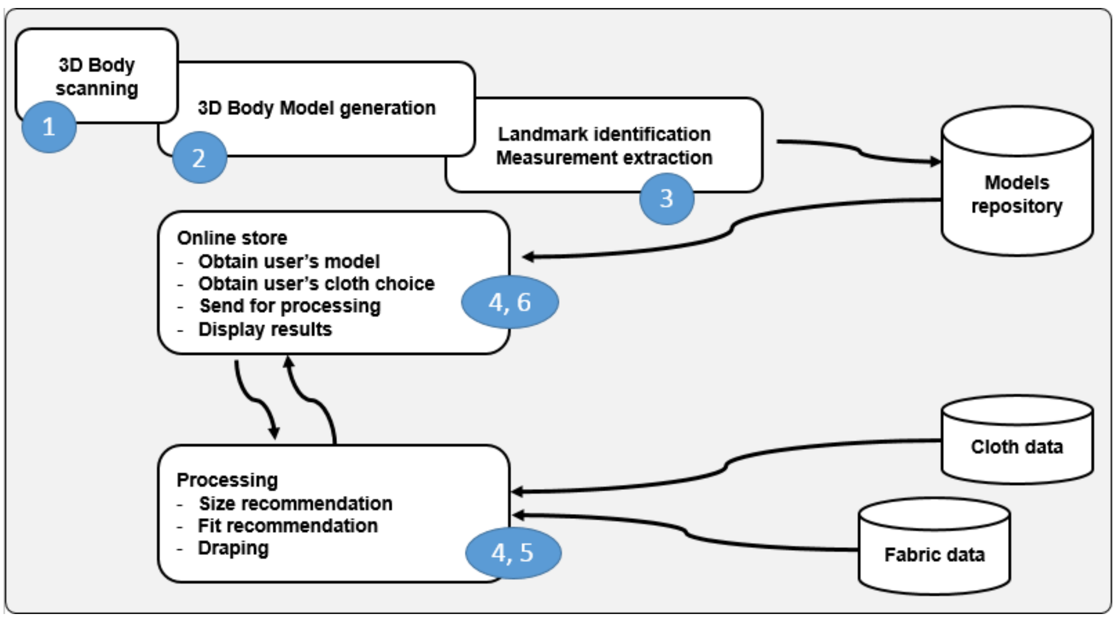

Figure 2: A possible 3D body processing flowchart (use case: fit recommendation)

Clearly, standardization is required if the flow involves different entities, companies, web sites, and databases, specifically in the following areas:

a. **Network Communication Protocols.** Today, developers of use cases must agree separately with database owners or service providers on how to exchange data and what application programming interfaces (APIs) are available for interacting with a service. With multiple vendors of end use cases, service vendors (e.g., model repositories; draping) will need to support multiple communication methods. Alternatively, aggregation vendors will need to write code that uses different protocols to exchange similar data with different vendors. Our goal is to select an existing network protocol that provides the needed functionality for requesting or delivering information as well as discovery of capabilities that an entity offers.

b. **Privacy.** Since body models contain user-specific data, the privacy of the users must be considered as part of the 3DBP initiative. Any protocol used to request body model data and any protocol used to exchange this data between cloud entities must include a layer of security to ensure privacy. Similarly, garment and cloth data must be protected since it is the property of the cloth or fabric designer/manufacturer. Our goal is to adopt one of the existing security protocols to support the 3DBP standard.

c. **File formats** (how the data is represented). Agreements are required for the following: how a body model is represented; how landmarks and measurements data are represented; how fabric information is represented; etc. for any additional data items. This will minimize the amount of effort required to aggregate and process data from different sources. It will also minimize the amount of code development needed to deal with inputs, regardless of the originating database. Our goal is to select one of the existing file formats that best fits our needs.

d. **Metadata.** Different use cases may benefit from additional data beyond the bare 3D model. For example, the use case described in Figure 2: would benefit if the file contained a number of attributes such as the following:
   - The model's landmarks and measurements data
   - Clothing and fabric attributes

   Other possible useful examples of metadata are the source of the model (the scanner model, including the SW version), information about the coordinate system used, the user, the body pose, etc.

   Our goal is to define the metadata that needs to accompany a 3D body model and suggest a method for ensuring that the data is indeed correct and not tampered with.

e. **Quality.** Today's 3D body model files include no information about the quality of the model. For example, information about the model's accuracy. Such information may be helpful, if only to reject a user's request when a certain aspect of the incoming model quality is not high enough to perform the use case reliably. Other examples for quality-related information is water-tightness; model's acquisition time (slow time = subject's movement impact the accuracy); whether some parts of the model were artificially generated; etc.

3. 3DBP use cases and associated attributes

We collected information on a number of apparel-related use cases that use 3D body-model processing. These use cases require certain data and metadata. The study of these requirements will help us define which items are important to standardization.

NOTE: We are well aware of other, non-apparel-related use cases (e.g., photo realistic avatars for animation). This white paper focuses on the apparel industry. The 3DBP initiative does intend to look into other use cases as well. The underlying assumption is that recommendations made for supporting interoperability in the apparel industry will be relevant to other use cases.

Use case descriptions

Use case 1: Fit and size estimation

Fit and size estimation services recommend which size of a particular garment would fit a potential buyer. Size recommendations are based on input from the buyer and knowledge about the sizing chart and/or manufacturing specification of the clothing manufacturer. In some cases, a fit recommendation provider may ask for subjective input from the buyer. (Do you prefer a tight fit? Loose fit?) Based on this data, fit and size estimators create a model of a user/buyer and match specific garment sizes to them.

Data extracted from 3D models can be used to replace and/or augment user-reported data or manual measurements that are used by the fit and size estimators to create a user model. This data could increase the accuracy of models.

Data from the model can be used to calculate fit in specific areas of the body that standard, physical measurements do not address—such as foot-size related measurements. They can also help with form-fitting garments, such as bras, shapewear, or swim suits.

In combination with an animator, draping the garment digitally over the user's body model enables the fitting engine to display where the garment fit is too tight or too loose.

Use case 2: Retail

The most obvious retail use cases are tightly linked to size recommendation and fit estimations. The following are examples:

- An in-store scanning booth for size recommendation and fit estimation.
- Size recommendation and fit estimation via online stores.

Other use cases take advantage of the availability of 3D models, such as the following:

- Retailers have access to style and cut information of merchandise they carry. With the availability of 3D models, it is possible to match specific styles to specific body types. The retailer can encourage shoppers to look at product lines they would otherwise not consider but which would fit them well.
- The retailer can use the customer body models to inform themselves about population body types and sizes. This data can be used to influence future styles and sizing systems.

With the proliferation of body scanning solutions, it is reasonable to expect that users' models will be generated by a plethora of scanning solutions. Retail software would need to accept input models generated by various sources. Standardization of formats and metadata should simplify the development of retail software. Adding accuracy information to the model data will allow retailers to understand what level of experience they can provide the customer based on the accuracy of the customer's model.

Eliciting statistical data from the models will be significantly simplified if all models are guaranteed to follow certain standards in term of data content, available metadata (such as standardized measurements and landmarks), and standard file formats.

Adopting standard protocols that guarantee privacy will reduce data security concerns by customers who want to know who owns the data, how it is stored, and future accessibility.

The different protocols for collecting body scans need to be standardized across pose, garments worn, scan formats, and quality of scan, to allow simpler retail-side software.

Use case 3: Clothing manufacturing

Apparel manufacturing driven off of 3D body scans is limited at this time in the marketplace. Made-to-measure (MTM) manufacturing is limited to specific factories, retailers, and product categories. Body scanning for product development is mainly used for extracting body measurements for semi-custom or mass production clothing.

3D body models can provide measurements to enable mass-customization manufacturing.

Development of software systems that allow for moving from a 3D body scan to a 2D pattern environment and back to a 3D representation of a garment in a simple and seamless manner would streamline the manufacturing process.

Compressible flesh avatars need to be developed in order to be able to further understand and provide the full range of ease over body requirements consumers require

Use case 4: CAD tool developers

Using 3D Fashion Design CAD software, virtual 3D garments can be constructed from 2D pattern data and can be draped onto a virtual 3D avatar or a scanned avatar. Apparel companies using 3D-CAD usually have their own virtual avatar, or an avatar provided by body form companies (e.g., Alvanon), obtained by 3D modeling or 3D scanning of the physical body form, to be imported into the 3D-CAD software.

Scanning technology is constantly evolving. Attempts to import scanning data into 3D-CAD are improving, as CAD tool developers move to develop made-to-measure (MTM) and virtual fitting services for the apparel industry.

The general procedure for constructing 3D garments with 3D-CAD software can be broken into following steps:

1. Making patterns in 2D space
2. Positioning 2D patterns around the 3D body space
3. Virtual stitching of the 2D patterns together
4. Simulating

In step 1, the accuracy of landmarks is of vital importance since 2D patterns are being drafted based on the measurements/sizes of the target body to achieve a good fit. The measurements are based on landmarks, whose placement accuracy should therefore be within ±5 mm.

In step 2, the landmarks on a 3D avatar are used as reference locations for choosing arrangement points around a 3D body. The accuracy of landmark placement is less important since the draping algorithms used by some of the CAD software can drape clothing correctly over the avatar even when the initial positioning of the clothing is not that accurate. Note that this applies only to some CAD software; some implementations do need accurate landmark placement to provide good draping results.

For the best possible results in step 4, the smoother the 3D body mesh, the better. In clothing simulation, sharp edged features (e.g., nails, ear, and hair.) bring about unpleasant results visually and computationally. To avoid this problem, collision-caps (which are very coarse and smooth mesh covering the sharp regions) are commonly used.

In addition, to effectively minimize the collision issues between garment and body, it is important for the garment and the body to be collision-free at the initial state of simulation.

In order to accommodate a wide variety of garments, it is necessary for the 3D body to have various poses (T-pose, A-pose, Y-pose, etc.).

Use case 5: Body model storage and service

With the increase in online shopping sites that support fit virtualization and specialized online/in-store platforms for MTM retailing and Mass Customization, there will be a benefit for users to have their body model available for access on line. We foresee companies that will offer a secure repository for body models.

Scan service providers can contract such repository service for storing models they generate. Users can select to sign up for such service to store their body model. Having an online-accessible model allows online shops to import (using the user's credentials) body models from the repository into the virtual fit engine.

The use case is not impacted by file format, metadata, or data quality. However, a standard protocol will make it much simpler for an online shop to import body models from any storage service without having to re-write the code to support different protocols.

4. Standardization vectors

The 3DBP initiative identified the following four vectors where standardization can help improve interoperability:

- File formats
- Communication
- Metadata
- Quality

Each of these vectors is described in some details in the paragraphs that follow. During 2017, the 3DBP group will aim to explore the current status of each of these vectors and make recommendation for standardization.

File formats

Some common formats used for body models include OBJ, STL, and PLY. Autodesk's FBX format (a proprietary format) is often used for the delivery of rigid and animated body models. X3D (based on the VRML format) continues to be developed by the Wed3D consortium (http://www.web3d.org/). Overall there are close to 40 different 3D file formats,[1] some offering unique features while others are a result of development evolution and of commercial competition.

The variety of formats mean that vendors who want to provide metadata about their body models must do so externally to the model's file, since many formats do not support the addition of metadata to the model's file.

Having no standard file format is causing pain to everyone in the industry as each vendor must be able to support a large variety of file formats. While we do not aim at solving this problem, the guidelines listed below will narrow the number of recommended file formats as the more simple formats do not have the facilities to meet the guidelines.

With 3D body-model files available from various sources on the cloud, the concern of data integrity increases. What guarantee does an application have that the model file it just received from a file storage service can be trusted to have valid and accurate data?

[1] https://en.wikipedia.org/wiki/Category:3D_graphics_file_formats lists 16 formats.
https://sharemy3d.com/faq_3d_file_formats lists 37 formats.
http://edutechwiki.unige.ch/en/3D_file_format lists 23 formats.

To remove this concern we intend to look at options to authenticate the data in the body-model file. This can be done using standard, publically-available methods that are supported by open source code.

Vendors may want to make some of the metadata available only to certain users (e.g., for a fee). A recommendation that all metadata is put into the model file must also include a way to hide some of this metadata from users who are not authorized to see it (e.g., for users who did not pay a fee). This means that it must be possible to encrypt parts of the metadata in the file while leaving the rest of the file unencrypted.

The 3DBP initiative guidelines for recommending a file format are as follows:

- Do not invent yet another format. Find existing format(s) that provide the functionality listed next.
- Support embedding of metadata as part of the file.
- Support mandatory metadata (defined field names and defined enumeration data when applicable; must not be NULL).
- Support optional metadata (defined field names and defined enumeration data when applicable; may be NULL or may not exist at all).
- Support vendor-specific metadata (defined structure but nothing else).
- Support file authentication.
- Support encryption of parts or all of the file.

Using standard formats to deliver 3D body assets will improve interoperability and decreases friction across different software and use cases. Including metadata that pertains to quality attributes and creation methods can aid in giving a better understanding of what the file contains, how the body model was produced, and how it can be used.

Communication

There are a number of protocols that provide facilities to exchange files and data between network (cloud) entities (for example: HTTP, FTP, and WebDAV). While any of these protocols can be used to exchange files, we are looking for a protocol that can support some other capabilities that we believe will simplify 3DBP implementations.

The 3DBP initiative guidelines for recommending a file exchange protocol are as follows:

- Do not invent yet another protocol. Find existing protocols that provides the functionality listed next.
- Recommend only one protocol.
- As the information we deal with (body scans—often with color image of the scanned person) contains private data, the protocol needs to be secure and provide encryption options.
- The protocol must support simple File Request/File Send operations.

An additional goal is to look for a protocol that can support a discovery stage, where entities exchange messages to find what services each entity provides and how these services can be accessed.

We intend to engage network experts to recommend the right protocol for the 3DBP needs.

Metadata

As stated in the File Format section, there is a lot of merit and engineering sense in adding metadata to the model file itself as opposed to having this metadata provided in a parallel file. It means that once a service has the model file it also has all the needed information about it, which would streamline the data-gathering step of a processing pipeline.

We intend to recommend the following three types of metadata:

- **Mandatory.** A compliant model file MUST contain this data. The definition of mandatory fields guarantees that every model creator calls the same things with the same names. It also means that consumers of compliant model files can rely on having certain data available.
- **Optional.** A model file MAY contain this metadata. Having this metadata defined means that if the data is available, it will be called the same by all practitioners.
- **Vendor-specific metadata.** The only thing that the standard will specify about these metadata is how they must be represented in the file. The metadata name and type can be anything the vendor chooses. Vendor-specific metadata may be encrypted.

A possible forth type would be industry-specific metadata. This is metadata that is of great value to a specific industry, but of little value to another. A compliant model file for use by a certain industry MUST contain this data. A compliant file for use by other industries MAY contain this data.

Here are some examples for metadata that may be considered by the 3DBP group. These are just examples for possible metadata. The group did not yet discuss metadata details.

Mandatory:

- Gender
- Units (are the coordinates in mm? cm?)
- Scanner name
- Scanner SW version

Optional:

- Body type
- Body pose

Vendor Specific

- Camera focal length
- Scan mode

Standardization will improve interoperability, which in turn will ease the development of innovative solutions using body models and accelerate scaling of 3D body-model-based applications.

Use cases drive what metadata is needed or will be helpful to have in a model file. An initial survey of the importance of certain metadata for the use cases listed in Section 3 is provided in Appendix A.

Quality

Generally speaking, body-model files do not contain information about their quality. Some information is implicit: large number of vertices usually means a potentially more accurate model, but this is not guaranteed. A model may be accompanied by landmark placement and measurements values, with no indication of accuracy or stability. Other attributes, such as model water-tightness, or model acquisition time can give relevant information to some use cases. For example, a very short acquisition time could mean that the scanned person was effectively immobile while scanned versus a long scan time, which guarantees some involuntary movement.

We intend to explore the various options to provide some quality-related information about the model and methods of best way to provide that information.

5. Summary and future work

The increase in availability of body scanning equipment combined with the expected proliferation of applications that use body models, justify efforts to standardize some of the interactions concerning 3D body models and associated data. Standardization will improve interoperability, which in turn will ease the development of innovative solutions using body models and accelerate scaling of 3D body-model-based applications. This white paper is the first in a series that introduces the 3D Body Processing (3DBP) initiative as well as high-level descriptions of status, plans, and recommendations.

The 3DBP initiative aims to make standard recommendations in the following areas:

- Formats, protocols, and security methods for exchanging of 3D body-model files as well as other data relevant to 3D body-model processing applications.
- Communication between entities that provide 3DBP services via the cloud
- Addition of mandatory, optional, and vendor-specific metadata to body-model data files
- Method for authenticating the information that is in the file (the model's data and metadata) and encrypting vendor-specific proprietary information.
- Methods for providing some information about the quality of the model that is in the file

Since landmarks and measurements (L&M) are metadata that the 3DBP initiative looks at for inclusion in 3D body-model files, we surveyed the existing L&M defined by ISO and other standard organizations and plan to recommend which definitions a compliant implementation shall support. The comparison details will be published in a second white paper by the 3DBP during the first quarter of 2017.

Additional white papers are planned to be released by the 3DBP initiative during 2017 as the team explores the topics of communication, file formats, metadata, and model quality.

Appendix A

Per use-case quality attributes requirements

The following table summarizes some of the attributes of data in a 3D body-model file. It grades how important each attribute is to each of the use cases listed in Section 3. Note that the body model storage and service use case is not mentioned, since the table here looks at metadata and data quality. These do not impact the storage use case.

1–5 scale

1: Not needed

2: Nice to have

3: Useful

4: Good to have

5: Must have

Table 1: Attributes of data in a 3D body-model file

Quality attributes requirements	Fit models	Retail	Clothing manufacturing	CAD developers	Comments/notes
Landmark repeatability	± 3 mm	±5 mm	±5 mm	±3 mm	
Landmark placement accuracy	Feet: ±2 mm Body: ±5 mm	±5 mm	±5 mm	±5 mm	
Measurement accuracy	Feet: ±2 mm Body: ±5 mm Body mass: ±2 kg	±3 mm feet ±5 mm body	±5 mm	±5 mm	
No holes criticality	4	4	4	5	
Noise (How tolerant is the use case to Noise in the model?)	2	2	2	2	
Certainty values for landmark placement	4	4	4	4	
Certainty values for measurement values	5	4	4	4	

Quality attributes requirements	Fit models	Retail	Clothing manufacturing	CAD developers	Comments/notes
Certainty values for model overall accuracy	5	4	4	4	
Certainty values for each point cloud point	1	1	1	1	
Consistency of vertex numbers	2	2	2	2	Helpful on the technical side but not necessary
Consistency of landmarks labeling	5	5	5	5	
Consistency of measurements labeling	5	5	5	5	
Consistency of pose (How important is it that all models are scanned using the same pose?)	1	4	4	2	
Maintaining measurements accuracy when moving the body Moving the body means changing poses e.g., A-pose, T-pose, Y-pose	4	5	5	4	
Measurement conditions information (Is it important that the model comes with information about the conditions under which it was taken?)	2	3	3	1	Examples for conditions: • Level of movement • Scan time • Type of clothes • (for feet): Weighted/ Unweighted
No gaps under the arm	2	5	5	4	
No gap between thighs	2	5	5	4	
Symmetricity (Is it important that the model is symmetric?)	1	5	5	1	

Quality attributes requirements	Fit models	Retail	Clothing manufacturing	CAD developers	Comments/notes
Pose identification	1	4	4	4	There is a need for some standard poses (e.g., T-pose, A-pose, Y-pose, Attention-pose) 1) for easy initial positioning of 2D-patterns around 3D-body, 2) for checking a good fit in various postures.

Citations

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NOTE: This source quotes a research done by Universität Regensburg, showing 25-50% returns. We could not find the link to the original research.

[3] Saleh, Khalid. "E-commerce Product Return Rate – Statistics and Trends." Invesp Conversions. http://www.invespcro.com/blog/ecommerce-product-return-rate-statistics/.

NOTE: This infographics is based on a number of sources (listed at the bottom of the infographic), and quotes 30% returns.

[4] Pettypiece, Shannon. "Online Surge Means Many Not-So-Happy Returns for Retailers." Bloomberg Technology. December 29, 2015. https://www.bloomberg.com/news/articles/2015-12-29/online-surge-leads-to-many-not-so-happy-returns-for-retailers.

NOTE: This interview quotes 30% return rate. Source of the data is unclear.

[5] Ewen, Lara. "How the future of fit could spell the end of retail returns." Retail Dive. July 7, 2016. http://www.retaildive.com/news/how-the-future-of-fit-could-spell-the-end-of-retail-returns/421972/.

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Consensus

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