Overview of software and file exchange formats in 3D and 4D body shape scanning

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Abstract

3D body scanning is well known in various application areas such as medicine, automotive, sports, clothing, product design and gaming. These models have some limitations in that they are unable to capture dynamic poses that can provide more information about real-time tasks and interactions with a real-life object, machine or environment. As a result, in the literature, to provide a more realistic movement of static shape models, researchers provided an idea of attribute kinematic capturing or "skeletal animation" as Biovision Hierarchy (BVH) file using a wearable inertial mocap system applied to a 3D statistical shape model, obtaining a "moving statistical shape" using exchange format in open source software like Blender. But in this case, the attribution was not a perfect attribution of the real-time capturing of a dynamic 3D body shape in real-time Nowadays, 4D body scanning can perform 4D measurements in real-time of dynamic body shape without using any wearable inertial mocap system that can occlude the scanning surface and represent a comfortable solution without influencing the performance of the user. In addition, 3D and 4D can be used in open and closed source software using specific file exchange formats for modeling and animation or interaction and integration with other devices, e.g., synchronization with pressure mat and force platform. In particular, open-source software represents a more intuitive, fast and inexpensive platform for performing animation, modeling, and file exchange formats in a multidisciplinary approach. Based on the previous assumptions, in this study, we will provide an overview of open and closed source software along with file exchange formats in 3D and 4D body scanning, looking at the advantages and disadvantages of their use in different fields of applications. Future research will focus on studying the interoperability of data interchange formats utilizing 4D scanning technology, with an emphasis on developing and validating a methodology using a universal skeleton capable of representing and rigging a real population capture.

Keywords: body scanning, dynamic anthropometry, file exchange formats, DHM

Introduction

Digital anthropometry appears with the first 3D body scan device, arise in 1987 with the Loughborough Anthropometric Shadow Scanner (LASS), as an advanced solution to digitally measuring three dimensional body shape, substituting traditional anthropometry based on the identification of anatomical points (landmarks) by palpation, which requires calipers or tape to take measurements (Brooke-Wavellet, Jones, West, 1994). Bartol et al. (2022) recently reviewed the body measurements using 3D scanning, focusing on describing the 3D scanning technologies, the body measurements, and their extraction and classification. While Heymsfield et al. (2018) presented a critical review of digital anthropometry, describing the techniques and the field of applications. However, from these reviews emerged the software used and the problematic issues related to the compatibility and interoperability of exchange data formats between software and a standard procedure of introducing or exporting them starting from survey databases. Indeed, the emergence of 3D body scanning technology around 2000 created the need to examine population variability between countries. The first survey appeared in 2000, entitled "CAESAR database", covering the USA (Cyberware) and part of Europe (NL and Italy, Vitus pro). This was followed by a survey from UK (Size UK, 2001-02, TC2), Japan (2004-10, Voxelan LPW-2000 Hamano engineering), France (2003-04, Vitus smart), Korea (Size Korea 2003-04, 2010, Cyberware and Hamamatsu), Romania (2007-09, Vitus Smart), Thailand (2007-2008, TC2), Spain (2007-2014, Vitus smart), Germany (2007-09, Vitus smart), India (2009-2010, Vitus smart), Brazil (2012, TC2), Belgium (Smart Fit, 2013, SYMCAD II TC2), Italy (2012-2013, Vitus pro), Portugal (2014, TC2), China (2018, Vitus smart), (Alemany, Ballester, Parilla, 2019). The databases use different body scanners and, consequently, different output data formats that are decided by the proprietary body scanning companies, limiting the interoperability. It appears that each body scanner tool is using a different data format such as: PLY, OBJ, WRL and STL, see Table 1.

Table 1. 3D body scanners (S), their light sources system (LS), and their data exchange formats (D).

S	Cyberware	Vitus Pro and Smart	TC^2	Hamamatsu Body Line	SYMCAD II TC^2	Voxelan LPW-2000 Hamano Engineering
LS	Laser	Laser	White light	Infrared light	White light	Laser
D	PLY	OBJ, STL	OBJ, STL	PLY	OBJ, STL, PLY	PLY

Consequently, it is necessary to study the interoperability of the data formats, especially when we are using the 3 dimensional body shape (DHM) file for importing and exporting in open and closed software programs (DHM tools) for successive elaboration. But in 2004, digital anthropometry was evolving with the evolution of the 3D scanning techniques (Werghi, 2007; Fan, Yu, & Hunter, 2004) that were able to map digitally the

3D geometry of the body surface in 4D scanning techniques (Liberadzki, Adamczyk, Witkowski, & Sitnik, 2018) where the geometry was evolving in time, adding a 4th dimension: time (Nowak & Sitnik, 2020). In 2004, 3dMD introduced the dynamic 4D system that captures the body in 1.5 milliseconds with dense markerless surface tracking (400 plus points), (John Tzou, Artner, Pona, Hold, Placheta, Kropatsch, Frey, 2014). While, in 2019, the Biomechanical Institute of Valencia introduced the 4D scanning device, Move4D, that delivers noise and artefact-free watertight dense mesh (99k triface) per frame (up to 180fps) with a spatial resolution of 1mm. One sequence's 3D models can be provided with point-to-point correspondence (50K landmarks) and rigged (23-joint skeleton), according to Parilla et al. (2019). 4D scanning technology with respect to optoelectronic systems is able to capture the movement without using any markers attached to the body, providing free natural movement with no contact, especially during COVID time. This possibility ensures maintaining distance and the deployment of less operators in the lab. In addition, the 4D scanning device can be synchronized with other biometrical signals without interfering with other optical sets, permitting the synchronization of 4D scanning technology with for example force plate signal for measuring postural control or gait, as it is possible in traditional standard optoelectronic motion capture systems. The processing software used in this technology is based on deep learning and a data-driven body model that includes shape, position, and soft-tissue deformation. The system exports PLY, OBJ, and FBX files, but not yet a BVH file. Furthermore, studying 3D body shape, soft tissue deformation, and texture in motion using high-resolution photogrammetric cameras opens up a new pathway into human-system and environmental interaction for personalization and customization in a variety of fields of application, including medicine, sport, clothing, automotive, and product design. In this scanning evolution, we are passing from using 3D scanning for animating DHM during different activities (functional measures) to capturing measurements during movement (dynamic measures), (Gupta, 2014). In both situations, we are reproducing a movement that requires additional data formats such as FBX files as in the case of the MOVE 4D device to track the vertices along the motion frames or rigging as association of the skeleton (bones) animation of an OBJ file using motions described in a BVH file that comes from an external device as an inertial mocap wearable system integrated into open source software (Scataglini, Danckaers, Haelterman, Huysmans, & Sijbers, J., 2018). According to the previous assumptions, the authors present an overview of exchange data formats in 3D and 4D scanning, considering open and closed software for DHM simulations.

Methods and Results

Data formats

Data formats can contain geometry, or texture and material information, a scene, rigging for animation, and encoding for animation. In this review we are selecting data formats that are used in 3D and 4D body scanners, such as OBJ, PLY, STL, FBX, and BVH (McHenry & Bajcsy, 2008). The OBJ (Wavefront Object) is an open file format that contains the geometry, specifically, the vertex position, the UV positions of each texture coordinate vertex, vertex normals, and the faces that make up each polygon, expressed as a list of vertices and texture vertices. By default, vertices are kept in counter-clockwise order, making explicit specification of face normals unnecessary. Although OBJ coordinates lack units, OBJ files can include scale information in a human-readable comment line. While the Polygon file format (PLY), also known as Stanford Triangle Format, contains three-dimensional data from the scanner that is described as a group of polygons. However, the PLY format can be used to specify color, the specification's core element list does not include capabilities for describing material properties, shading, or the usage of images to define surface appearance. The STL file is a file format known as "standard triangle language or standard tessellation language" that is used more for 4D prototyping, 3D printing, and computer-aided design (CAD). The STL represents the surface of objects as a mesh composed completely of triangles, which is only sufficient for elementary geometry. A higher model resolution necessitates a bigger number of triangles, increasing the file size nearly tenfold. While OBJ contains several polygons in a single file and allows for exact surface encoding. Instead of facet forms, surfaces can instead be specified by Non-Uniform Rational Basis Splines (NURBS) patches, resulting in a considerably smoother and more realistic depiction. Nevertheless, this comes at the expense of bigger file sizes. OBJ, on the other hand, comprises several polygons in a single file and enables precise surface encoding. Surfaces can be described by NURBS patches rather than facet forms, resulting in a much smoother and more realistic representation. This, however, comes at the expense of larger file sizes. While its FBX (Filmbox) format comprises geometry, animation, and scenes. Although the FBX file format is proprietary, the format definition is available in the FBX Extensions SDK, which includes header files for FBX readers and writers (Peters, Wischniewski, Paul, 2019). Regarding the motion data, Biovision Hierarchical Data (BVH file) developed by motion capturing company Biovision contains two parts: one that describes the hierarchy and initial pose of a skeleton and a second part with motion data. In this case, the skeleton that is used for rigging and animation comes from devices such as wearable inertial mocap systems that have the number of joints that are configured by the company itself. It means that it can differ from company to company in the number of joints of a skeleton of a wearable mocap system, affecting not only the quality of the rigging and animation but also the compatibility, (Paul & Scataglini, 2019).

Open and closed source software for animating the 3D shapes of digital humans

In this section, we are collecting all the software open source (OA) and not open source (N-OA) with relative data formats that are used for elaborating body shape data for different purposes in different fields of application.

Table 2. Open (OA) and closed source software (N-OA), their website and exchange data format (D)

Name	**Website**	**(OA) and (N-OA)**	**D**
3ds Max	https://www.autodesk.be/	N-OA	STL, OBJ
Blender	https://www.blender.org/	OA	FBX, OBJ, PLY, STL
Cinema 4D	https://www.maxon.net/en/cinema-4d	N-OA	FBX, OBJ, STL
Clara.io	https://clara.io/	OA	OBJ, PLY, STL, BVH
Daz Studio	https://www.daz3d.com/daz_studio	OA	OBJ, FBX
IClone7	https://www.reallusion.com/iclone/	N-OA	BVH, FBX, OBJ
Maya	https://www.autodesk.fr/products/maya/	N-OA	OBJ, STL
Unity	https://store.unity.com/	N-OA	FBX, OBJ

Importing different data format and 4D scanning in Clara.io

In order to test the interoperability of the data formats coming from 4D scanning, an FBX file representing a subject that is walking was imported into Clara.io open software. The file shows only the rigged 23 joints skeleton but not the body mesh. Therefore, to understand the interoperability of BVH file, we decided to import the BVH file of wearable motion capturing system as Yost Labs (17 joints skeleton) and Xsens (22 joints skeleton) into Clara.io, see Figure

1. All the skeletons can be used for rigging and animation of body shape, but one of them comes from a 4D scanner (MOVE 4D, IBV, Valencia). As a result, we can see that a universal skeleton that is used for motion capturing does not exist.

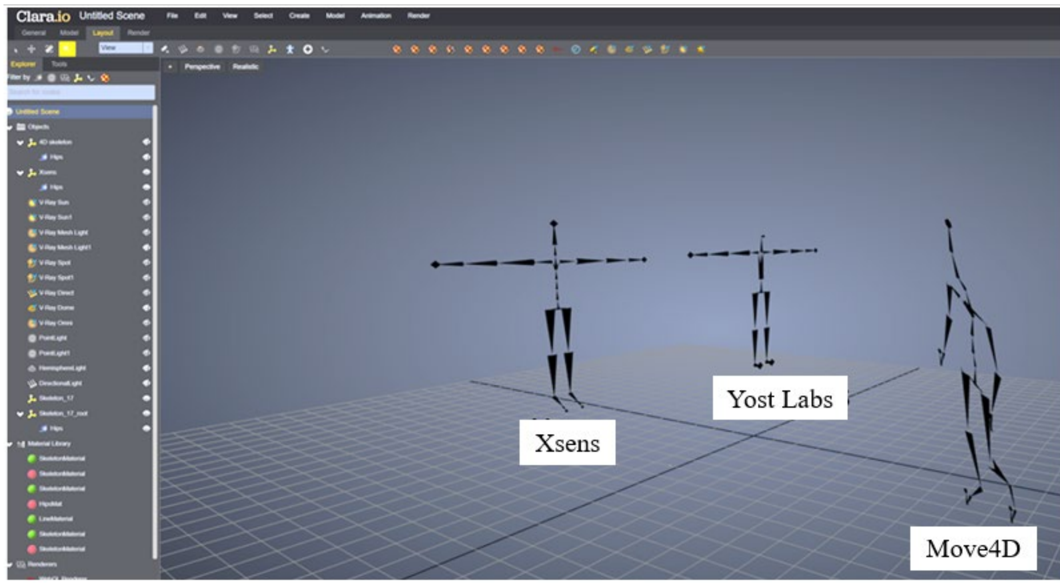

Figure 1. Importing of two BVH files coming from Xsens and Yost Labs wearable mocap systems and a FBX file from 4D scanning for Move4D in Clara.io.

Discussion and Conclusions

In marker-based movement analysis, markers are positioned on the body for the estimation of the joint positions and, consequently, the movement. In 4D scanning, without using any markers, we can identify the vertex of the homologous mesh (Karoui, M.F., Kuebler, T. (2019) that represents the same position as a marker-based movement analysis system to identify and calculate the joint positions (Faisal, Majumder, Mondal, Cowan, Naseh, & Deen, 2019). If we compute the structure of the skeleton using the kinematic approach with the vertex of the homologous anatomical points, the joints that we obtain are different from the joints that are used in the rigging. As a consequence, we have two skeletons that have the same structure of bones and joints but the position is different. The animation obtained with the traditional optoelectronic system respects the animation obtained using the inertial measurement system, which is different. The two models are obtained in different ways: one is based on the markers positioned on the body to identify the structure, while the other is based on the inertial sensors positioned in different locations to animate the mesh. Accordingly, it is necessary to have a universal skeleton (Wu & Cavanagh, 1995) that can be used internally for the rigging and externally from the vertices of the 3D mesh that communicate in a data format such as the BVH file. Therefore, in DHM, one of the problems that we are encountering with the introduction of the 4D scanning technologies is not only related to data formats but also to skeleton formats. In inertial wearable measurement systems such as Xsens, the positions of anatomical landmarks are not measured directly as in optical mocap systems (Roetenberg, Luinge & Slycke, 2009), but calculated using the measured segment kinematics in combination with the anatomical model (Mavor, Ross, Clouthier, Karakolis, & Graham, 2020). Sfalcin et al., 2019 compared an optical system with two inertial full mocap measurement systems (Xsens and Perception Neuron) using Jack ™ found errors in joint kinematics. The Xsens system reduced this error. However, the authors suggest using optoelectronic traditional systems for their accuracy respecting the inertial measurement units, especially when the animation is used for ergonomics assessments. Indeed, if we are animating a static file, for example, in Blender, we are losing the potential of the scanner that is capturing the external 3D shape in each frame of the movement. If we are comparing the same frame animated with the rigging in Blender with a 4D scan, then we can see that the surface of the body is different. The solution should be to use exchange data that can combine the rigging animation that is more "artistic" with a real scan using 3D in a real way. Scataglini et al. (2019) animated a static mesh from the CAESAR database in Blender using a BVH file obtained from the inertial measurement mocap system Xsens without using an optoelectronic system. However, no comparison in accuracy of the animation using the rigging from Xsens and optoelectronic systems was studied, representing a limitation. As a result, future research will focus on studying the interoperability of data interchange formats utilizing 4D scanning technology, with an emphasis on developing and validating a methodology using a universal skeleton capable of representing and rigging a real population capture.

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