International Standard

# ISO 17097

# 3-D human body scan data — Methods for the processing of human body scan data

*Données de numérisation 3D du corps humain — Méthodes relatives au traitement des données de numérisation du corps humain*

First edition
2024-05



Reference number
ISO 17097:2024(en)

# Contents

Page

# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 3, *Anthropometry and biomechanics*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

# Introduction

Three-dimensional (3-D) human body scan data are the digitized 3-D shape information of the human body in the form of a point cloud. 3-D body scanners or 3-D image-capturing systems are used to obtain these data. The collected 3-D point-cloud data are processed using 3-D scan data processing software and then used for anthropometric measurement, body shape analysis and ergonomic product design.

Knowledge and experience in the processing and analysis of 3-D point-cloud and mesh are required to improve the quality of human body scan data while maintaining their morphological characteristics for their application to the design of a particular product, workplace or system. Custom software can be developed to support the processing of human body scan data by incorporating terms, methods and considerations in this document in a selective manner.

This document is intended to be used by software developers during the development of scan data processing software. It could also be helpful for anthropometric researchers and product designers when they establish 3-D human body scan databases to analyse human body shape and size. A 3-D human body scan database could benefit manufacturers, customers and employees by developing products, workplaces and systems with better fit, comfort and usability.

The purpose of this document is to enhance the utilization of 3-D human body scan data through appropriate processing. It is further intended to improve the accuracy and reliability of analysis of 3-D human body scan data.

# 3-D human body scan data — Methods for the processing of human body scan data

## 1 Scope

This document specifies methods for the processing of human body scan data acquired using a 3-D body scanner.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7250-1, *Basic human body measurements for technological design — Part 1: Body measurement definitions and landmarks*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7250-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

### 3.1 3-D anthropometry

**3.1.1**
**3-D body scanner**
hardware and software system that creates data representing a human form, or parts thereof, in three dimensions

[SOURCE: ISO 20685-1:2018, 3.2, modified — “creates digital data” has been replaced by “creates data” in the definition.]

**3.1.2**
**3-D scanner hardware**
physical components of a 3-D body scanner and any associated computer(s)

[SOURCE: ISO 20685-1:2018, 3.4]

**3.1.3**
**3-D scanner software**
operating system, user interface, programs, algorithms and instructions associated with a 3-D scanning system

[SOURCE: ISO 20685-1:2018, 3.3]

**3.1.4**
**anatomical landmark**
point clearly defined on the body that can be used for defining anthropometric measurements

[SOURCE: ISO 20685-1:2018, 3.6]

## 3.2 3-D scan data

**3.2.1**
**3-D scan data**
collection of the coordinate values of either 3-D points or the connection information of the 3-D points, or both

**3.2.2**
***x*, *y*, *z* coordinate system**
**axis system**
system for measuring the body with respect to the standing or sitting human where *x*, *y* and *z* refer to the fore-and-aft direction (the sagittal axis), the side-to-side direction (the transverse axis) and the top-to-bottom direction (the longitudinal axis), respectively

[SOURCE: ISO 20685-1:2018, 3.13, modified — the content of the definition has been restructured and Note 1 to entry has been removed.]

**3.2.3**
**point cloud**
collection of 3-D points in space referenced by their coordinate values

Note 1 to entry: See Table 1.

**Table 1 — Point cloud consisting of *n* 3-D points**

| Point index | Column 1 (*x*-coordinate) | Column 2 (*y*-coordinate) | Column 3 (*z*-coordinate) |
|---|---|---|---|
| 1 | 2,56 | −21,94 | 91,31 |
| 2 | 2,69 | −20,89 | 90,01 |
| 3 | 2,11 | −22,83 | 92,84 |
| ⋮ | ⋮ | ⋮ | ⋮ |
| *n* − 2 | −28,57 | −17,08 | −27,89 |
| *n* − 1 | −9,69 | −19,81 | −29,03 |
| *n* | −19,92 | −9,61 | −33,74 |

[SOURCE: ISO 20685-1:2018, 3.9, modified — Note 1 to entry has been replaced and Table 1 has been added.]

**3.2.4**
**texture**
visual information of colour in 3-D scan data

Note 1 to entry: The texture of each point is expressed as a value between 0 and 255 for the individual colours of red, green and blue, as shown in Table 2, in the .ply file format.

**Table 2 — Point cloud consisting of *n* points with texture information**

| Point index | Column 1 (*x*-coordinate) | Column 2 (*y*-coordinate) | Column 3 (*z*-coordinate) | Column 4 (red) | Column 5 (green) | Column 6 (blue) |
|---|---|---|---|---|---|---|
| 1 | 2,56 | −21,94 | 91,31 | 127 | 127 | 127 |
| 2 | 2,69 | −20,89 | 90,01 | 123 | 133 | 138 |
| 3 | 2,11 | −22,83 | 92,84 | 92 | 97 | 215 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| *n* − 2 | −28,57 | −17,08 | -27,89 | 238 | 200 | 210 |
| *n* − 1 | −9,69 | −19,81 | -29,03 | 255 | 230 | 243 |
| *n* | −19,92 | −9,61 | -33,74 | 255 | 255 | 255 |

**3.2.5**
**vertex**
**node**
intersection of two or more lines, curves or edges

**3.2.6**
**triangle face**
surface (face) created by connecting three adjacent vertices

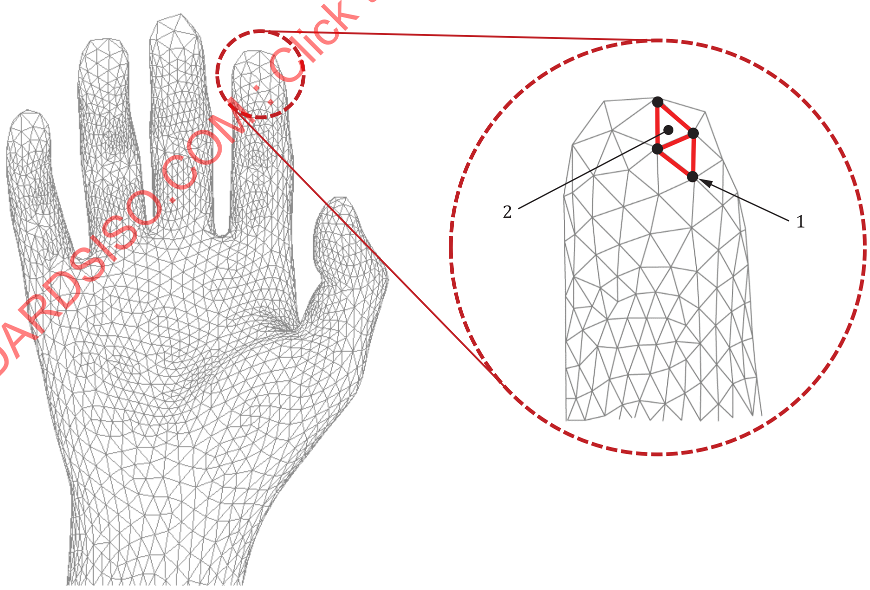
**3.2.7**
**mesh**
surface consisting of a set of vertices, edges and faces that define the shape of an object

Note 1 to entry: A triangular mesh consisting of a set of triangle faces (each of which is defined by the indices of three vertices, as shown in Table 3) is used to construct the 3-D digital form of the human body, as shown in Figure 1.

**Table 3 — 3-D scan data presented by a triangular mesh with *m* triangle faces**

| Triangle face index | Column 1 (point index of the first vertex) | Column 2 (point index of the second vertex) | Column 3 (point index of the third vertex) |
|---|---|---|---|
| 1 | 1 | 2 | 3 |
| 2 | 1 | 2 | 4 |
| 3 | 1 | 3 | 5 |
| ⋮ | ⋮ | ⋮ | ⋮ |
| $m - 2$ | 8 345 | 8 346 | 8 347 |
| $m - 1$ | 8 347 | 8 348 | 8 349 |
| $m$ | 8 347 | 8 348 | 8 350 |






**Key**
1 vertex
2 triangle face

**Figure 1 — 3-D human scan data in triangle faces**

## 3.3 Processing of 3-D human scan data

**3.3.1**
**point-cloud processing**
manipulation of point cloud and texture data acquired by 3-D scanner hardware by applying operations such as merging, noise removal, meshing, resolution adjustment and texture mapping

**3.3.2**
**mesh processing**
manipulation of a mesh by applying operations such as hole filling, merging, smoothing, mesh subdivision, decimation, remesh, landmarking, alignment and template matching

**3.3.3**
**resolution**
density of vertices and triangle faces that consist of 3-D scan data

# 4 Methods for point-cloud processing

## 4.1 General

A point cloud obtained by scanning the human body shall be processed by one or more of the following operations: [11],[17],[19],[40],[46]

— registration (4.2);

— merging (4.3);

— denoising (4.4);

— adjustment of point-cloud resolution (4.5);

— meshing (4.6);

— texture mapping (4.7);

— saving of mesh (4.8).

NOTE The point-cloud processing operations are performed automatically or semi-automatically by 3-D scanner software or manually by using 3-D scan data processing software while following a general procedure of point-cloud processing, as shown in Figure 2.

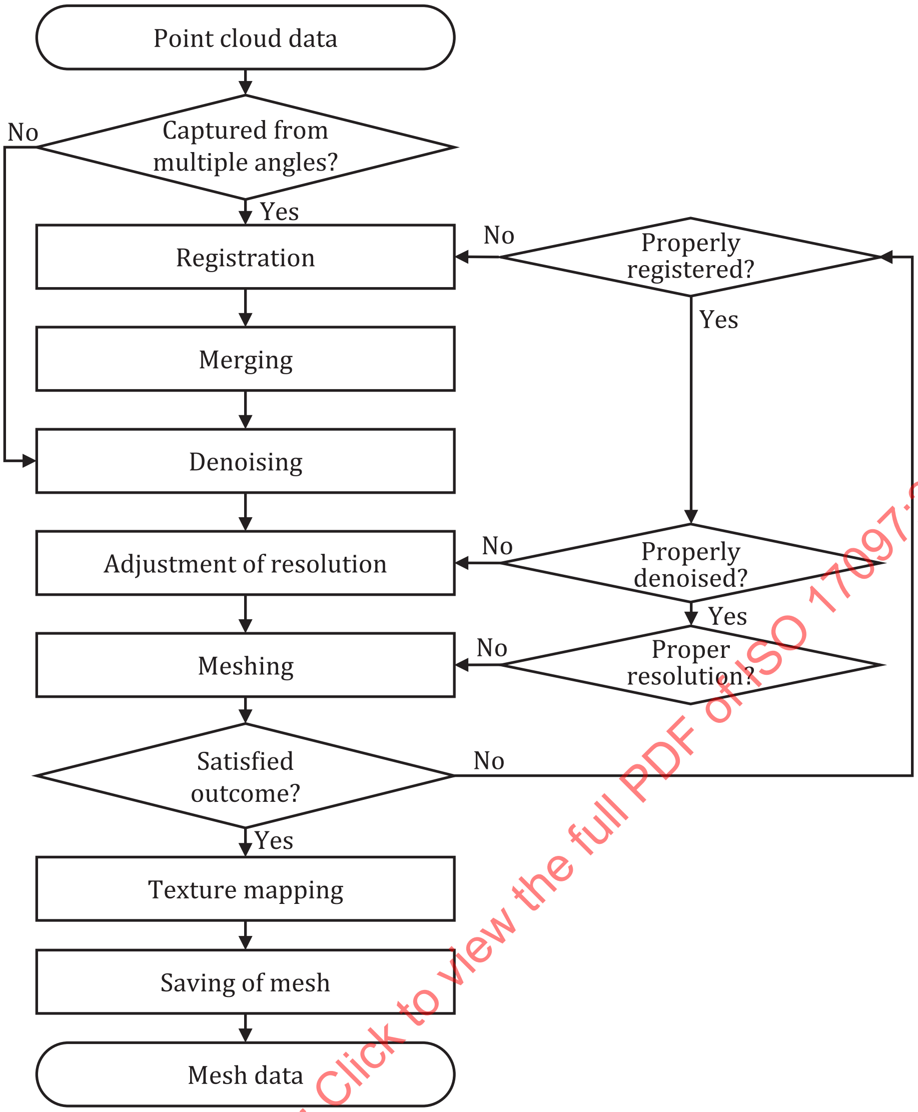



**Figure 2 — General procedure of point-cloud processing**

## 4.2 Registration

When a 3-D body scanner consisting of two or more cameras captures the human body from different angles simultaneously, sets of point-cloud data obtained from the different cameras shall be registered based on one or more areas in common.[25],[28],[40],[44]

NOTE 1 A 3-D body scanner consisting of multiple cameras generally requires calibration for automatic registration of point-cloud sets, which are captured from different angles.

NOTE 2 If point-cloud sets are separated from each other, a manual registration function provided by 3-D scanner software can be used to make point-cloud sets appropriately aligned through manually determining pairs of the corresponding areas (see Figure 3).

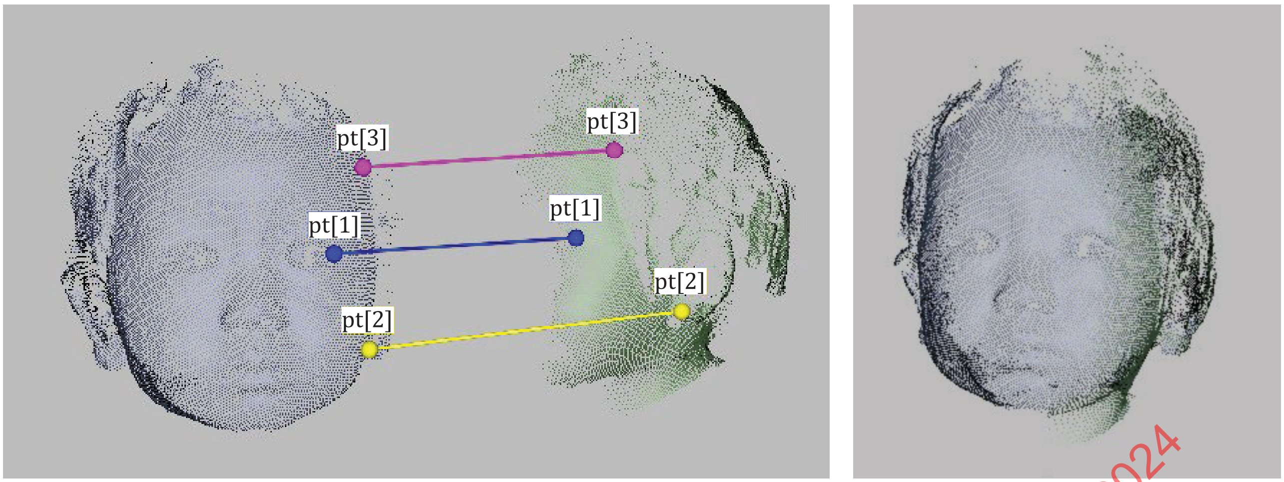



**Figure 3 — Manual registration of point-cloud sets**

NOTE 3 An inaccurate registration can occur if common areas of point-cloud sets are morphologically unequal, which is caused by breathing or postural change. In these cases, a non-rigid registration can be applied to match point-cloud sets precisely by adjusting the location of vertices.[19],[40]

## 4.3 Merging

The sets of registered point-cloud data should be combined into a single point-cloud set for further processing steps.[19],[35]

## 4.4 Denoising (noise removal)

Points that are not part of the human body but are included during the process of human body scanning shall be removed.[19],[31]

NOTE 1 Noise in 3-D scan data can be caused either by a poor quality imaging system (e.g. low resolution of 3-D scanner hardware, improper focal length, inappropriate calibration) or by environmental interference during the image-capturing process (e.g. light intensity), or both.

NOTE 2 Denoising function with parameters (e.g. denoise method, denoising intensity, iteration of denoising process) provided by 3-D scanner software is used to filter noise. The effect of noise can be recognized once point-cloud data has meshed in consequence. If the resulting mesh shows an unclean surface partly or overall, denoising with adjusted parameters can be applied until an improved mesh is obtained.

If noise in the point-cloud data of the human body is not properly removed, the surface of the corresponding mesh can have many significant irregularities, as shown in Figure 4. If significant noise occurs repeatedly, then the focal length of either the scanner's lenses or the light intensity, or both, should be checked and the scanner should be recalibrated if needed.

**Figure 4 — An inappropriate scan result with significant noise**



### 4.5 Adjustment of point-cloud resolution

The resolution of point-cloud data should be adjusted by controlling the number of points in the point-cloud data. The 3-D scanning system adjusts the number of points that constitute the surface of the scanned object so that the spacing between the vertices is kept within a designated range of distance (e.g. 1 mm to 2 mm).

NOTE 1 A resolution adjustment function with parameters (e.g. average distance between vertices, target number of vertices) provided by 3-D scanner software is used to change the density of the point cloud.

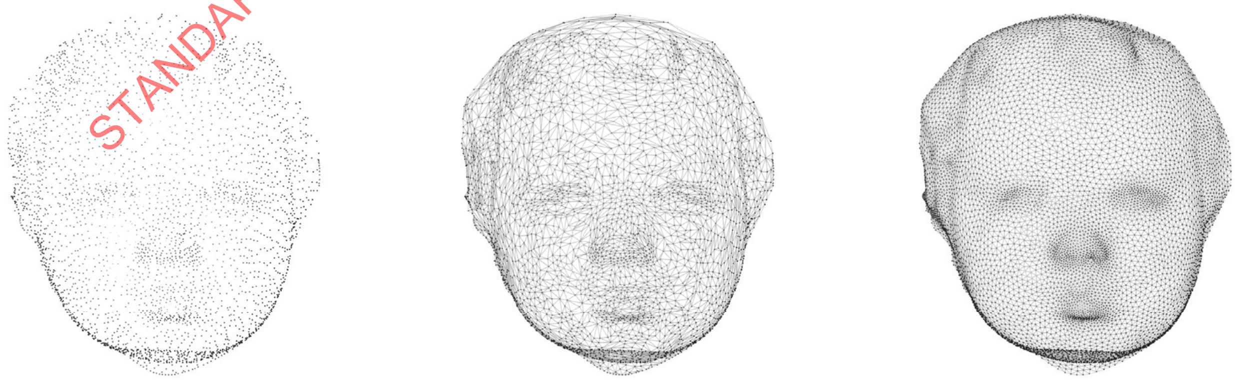
NOTE 2 When the density of a point cloud is high, the resolution of the point cloud can be reduced to keep a smaller number of points. A lower density of a point cloud enables faster data processing and analysis.

NOTE 3 The resolution of a 3-D scanned image can also be adjusted in the mesh processing.

### 4.6 Meshing

Triangle faces for visualizing the surface of the human body should be formed by connecting adjacent points in the point cloud.

NOTE 1 Once meshing is completed, a mesh topology can be reconstructed (e.g. remesh) by repositioning vertices along the meshed surface while considering distances between vertices (Figure 5). A remesh step can also be conducted in the mesh processing.



**a) Point-cloud** **b) Mesh** **c) Remeshed outcome**

**Figure 5 — Meshing**

NOTE 2 If the meshed surface is not satisfied, the previous steps (e.g. registration, denoising or resolution adjustment) with adjusted parameters can be conducted iteratively until a satisfactory mesh is obtained.

### 4.7 Texture mapping

When a 3-D body scanner acquires the colour data of the human body together with the corresponding shape data, an RGB colour value shall be assigned to each vertex or face.

### 4.8 Saving of mesh

The processed 3-D human body scan data is saved in the form of a file containing a list of vertices and a list of triangle faces. When saving the processed 3-D human body scan data, the 3-D scanner software shall allow the user to select the desired file format among those commonly used.

NOTE 1 File formats commonly used to store 3-D human body scan data include .obj, .ply, .stl, .wrl and .iv.

NOTE 2 Various file formats differ in recording lists of vertices and triangle faces. Although the file formats are interchangeable, some file types (e.g. .stl) cannot store texture information, whereas the .ply file format can store texture information.

NOTE 3 Some 3-D scanner software saves image files, such as .jpg and .bmp, and a material template library file, such as .mtl, separately, in addition to a text file containing the list of vertices and the list of triangle faces.

## 5 Methods for mesh processing

### 5.1 General

A mesh produced by the processing of a point cloud is processed by one or more of the following operations: [13],[14],[18],[19],[29],[33],[36],[42]

— editing of mesh (5.2);

— adjustment of mesh resolution (5.3);

— landmarking for mesh alignment (5.4);

— alignment of mesh coordinates (5.5);

— template matching (5.6).

NOTE The mesh processing operations are performed manually or semi-automatically by 3-D scan data processing software by referring to a general procedure of mesh processing shown in Figure 6.

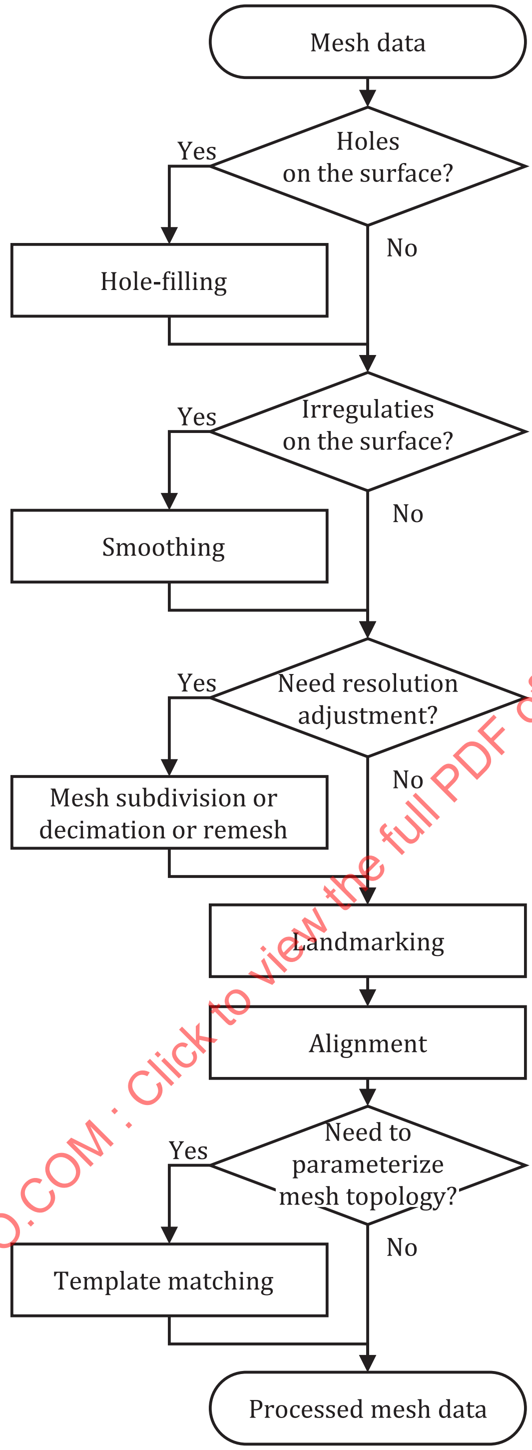





**Figure 6 — General procedure of mesh processing**

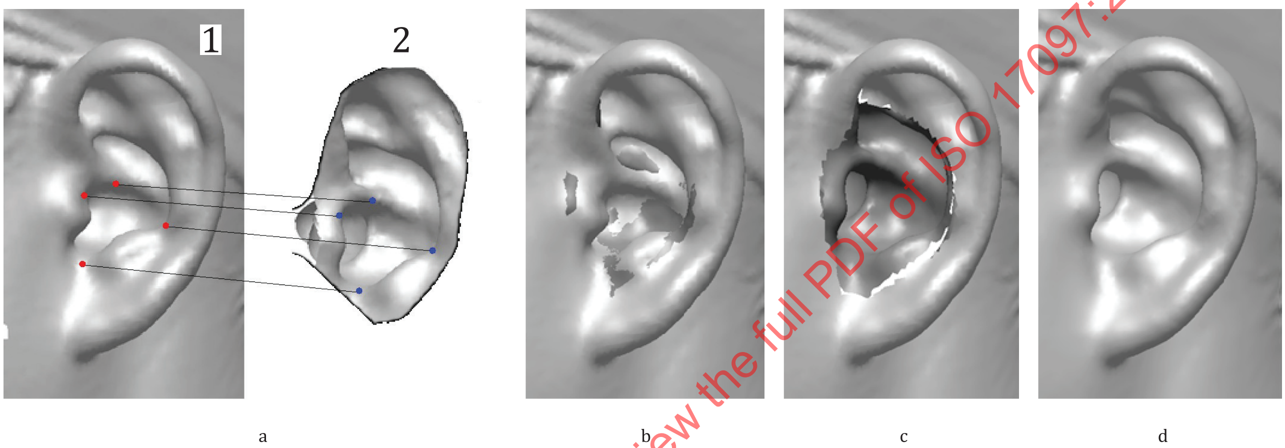
## 5.2 Editing of mesh

### 5.2.1 Merging

If a part of the human body is not scanned due to the limitation of the camera angle of view during 3-D human scanning, the missing body part should be scanned separately and then merged with the previously scanned body part.

NOTE Examples of human body parts that are difficult to scan in 3-D due to the complexity of the body shape and the limitation of the camera angle of view include the armpits, the crotch, the area under the chin, the areas between the fingers and the area in the ears.

EXAMPLE An ear scan without a missing part can be produced as shown in Figure 7 by merging an ear scan with missing parts and a scan of a mould of the concha and external auditory meatus. The mould of the concha and external auditory meatus that are difficult to scan can be prepared by using rapidly curable material used in manufacturing a hearing aid.




**Key**

1 scan of the ear with missing parts

2 scan of a mould of the concha and external auditory meatus

a Selecting points on the ear scan with missing parts and their corresponding points on the mould scan of the concha and external auditory meatus for the registration of the two scans.

b Registering the mould scan to the ear scan.

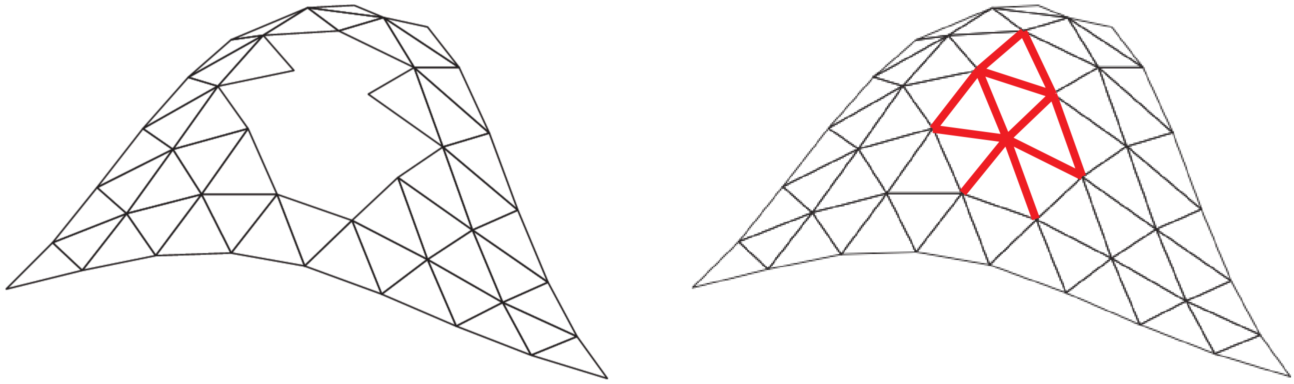
c Removing the area of the concha and external auditory meatus from the ear scan.

d Merging the mould scan with the ear scan.

**Figure 7 — Correction of an ear scan with missing parts of the concha and external auditory meatus by merging**

### 5.2.2 Hole-filling

The hole on a mesh should be filled by creating points through interpolation inside the hole by referring to the shape and curvature information around the hole. A hole is filled in general by creating new vertices in the hole through interpolation using information from the vertices around the hole and then connecting the new vertices and the vertices around the hole by triangle faces (see **Figure 8**).

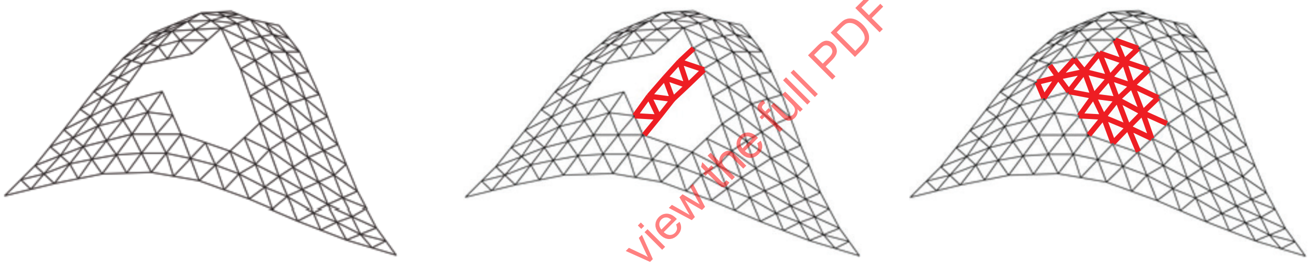


a) Before b) After

**Figure 8 — Hole-filling**



NOTE A bridge function provided by 3-D scan data processing software can be used to fill a large missing area (see Figure 9). One or several bridges are constructed across the missing area by referring to the shape of the surrounding area measured. The constructed bridges divide the large missing area into several smaller holes and then these holes are filled. Filling a large missing area naturally with a bridge function requires skill.

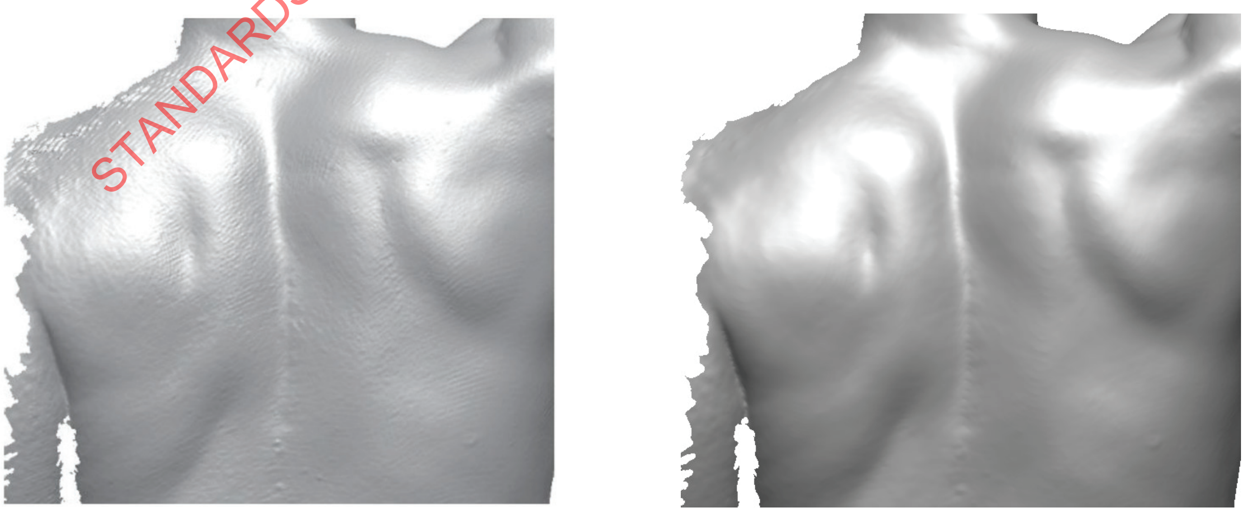


a) Before b) Forming a bridge c) After

**Figure 9 — Filling a large missing area with a bridge function**

### 5.2.3 Smoothing

Irregularities on the surface of the 3-D human body scan data should be smoothed (see Figure 10).



a) Before b) After

**Figure 10 — Smoothing**

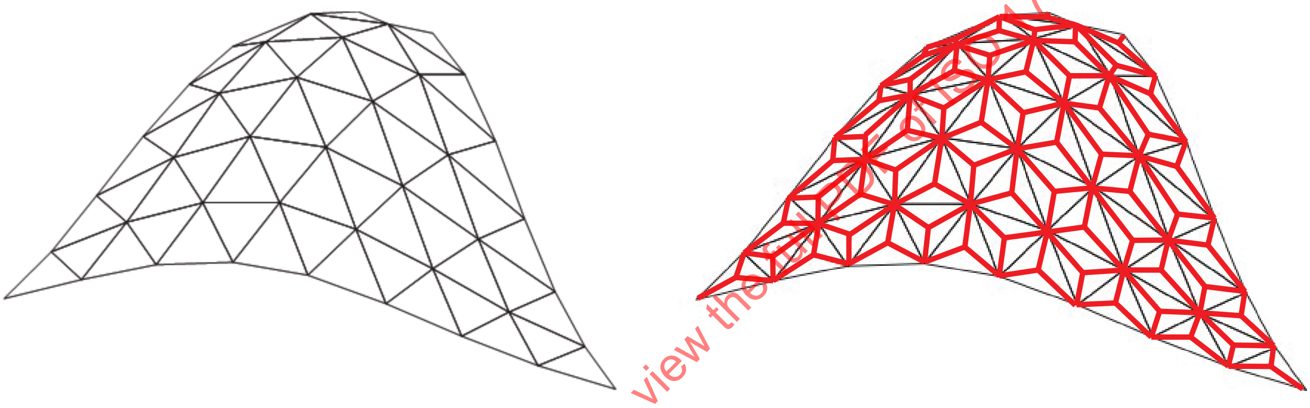
NOTE If excessive smoothing is applied to the surface of 3-D human body scan data, details of the body scan with large curvatures or complex shapes can be lost (e.g. shoulder, armpit, nose, chin, ear and finger).

## 5.3 Adjustment of mesh resolution

### 5.3.1 Mesh subdivision

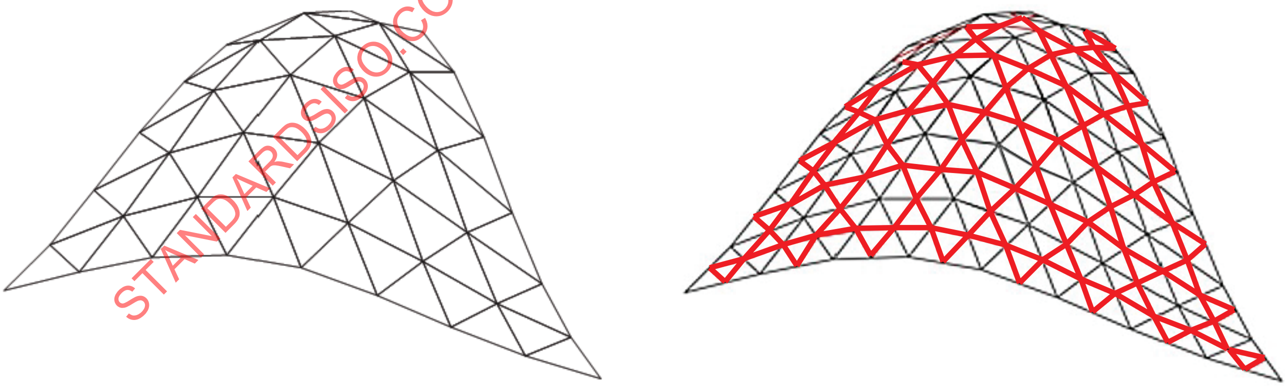
The number of vertices or triangle faces in a mesh shall be increased if a more detailed shape of the human body is required by subdividing each face into smaller faces. The shape of the human body is precisely expressed when the number of triangle faces constituting the digital 3-D human body scan data becomes large.

NOTE A mesh can be subdivided by adding a point at the centre of each triangle face to trisect the face, as shown in Figure 11, or by adding a point to the midpoint of each face edge to quaternize the face, as shown in Figure 12. Mesh subdivision enhances the mesh resolution but decreases the speed of data processing and analysis. Nevertheless, subdividing a low-resolution mesh will not improve the precision of the original scans.



**a) Before** **b) After**

**Figure 11 — Trisection of triangle faces by mesh subdivision**



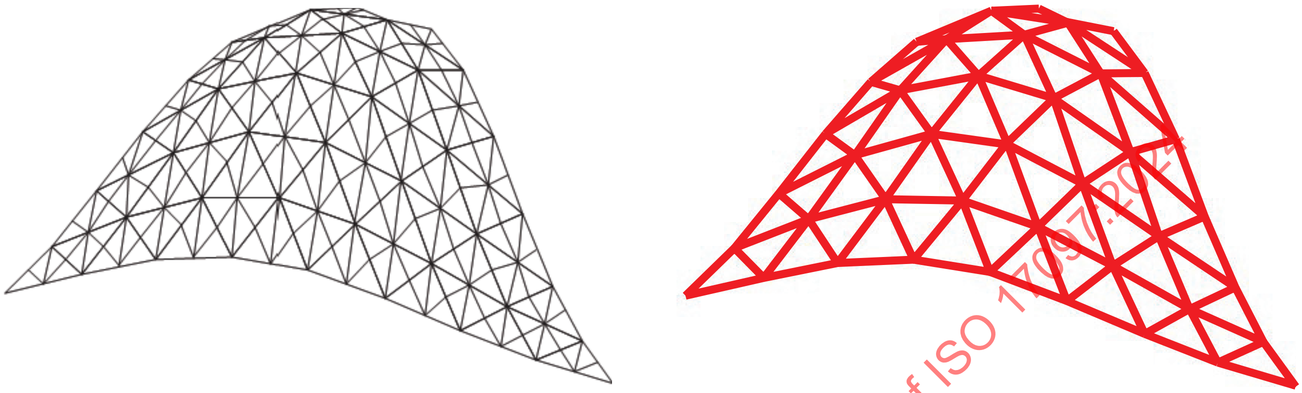
**a) Before** **b) After**

**Figure 12 — Quaternization of triangle faces by mesh subdivision**

### 5.3.2 Decimation (mesh downsampling)

The number of vertices or triangle faces in a mesh shall be decreased if a smaller memory size of the human body scan data is required. However, reducing the number of triangle faces comprising the digital 3-D human body scan data diminishes the resolution of the human body,

NOTE The number of vertices or triangle faces in a mesh can be reduced by removing arbitrary points with a designated ratio (e.g. 50 %). Subsequently, new triangle faces are constructed with the remaining vertices or newly generated vertices on the mesh, as shown in Figure 13.[12],[20]

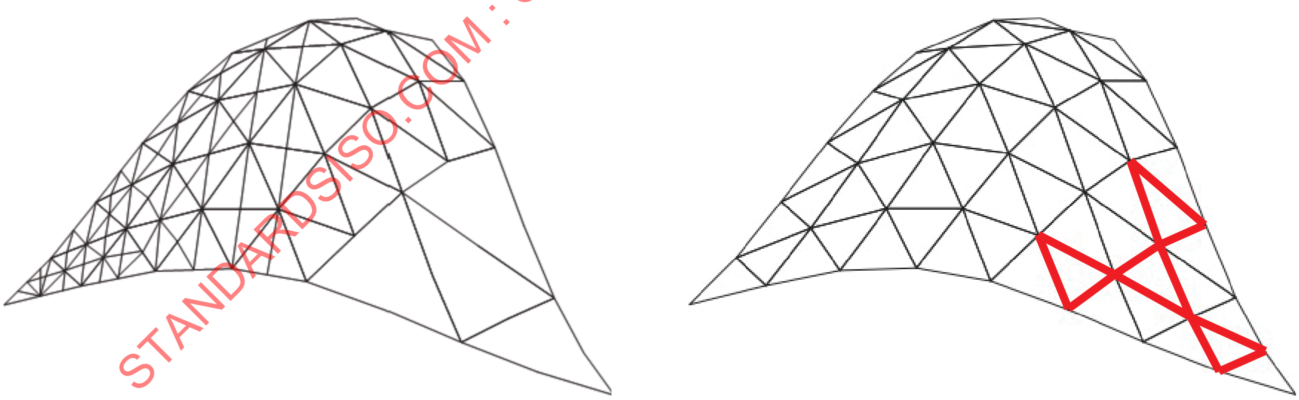


a) Before b) After

**Figure 13 — Decimation**

### 5.3.3 Remesh (mesh optimization)

The positions of the vertices in a mesh should be rearranged so that the distances between the vertices constituting the human body become uniform or optimized without significantly deforming the 3-D human body shape (see Figure 14).[9],[10],[41] The sizes of triangle faces are adjusted by specifying the spacing between vertices.



a) Before b) After

**Figure 14 — Remesh**

NOTE When restructuring a mesh in the 3-D scan data processing software, the vertices can be spaced in inverse proportion to the curvature of the body part. The method of narrowing the distance between vertices is used for parts of the human body with large curvature (e.g. nose, eye sockets, armpits and fingers) to keep the detailed shapes of the body parts. However, the opposite applies to body parts with small curvature (e.g. cheeks, thighs and back).

## 5.4 Landmarking for mesh alignment

Anatomical landmarks should be identified on a 3-D human mesh model for the alignment of 3-D human body scan data.

NOTE 1 Anatomical landmarks can be identified by referring to ISO 7250-1. Anatomical landmarks can also be used to measure human body dimensions.

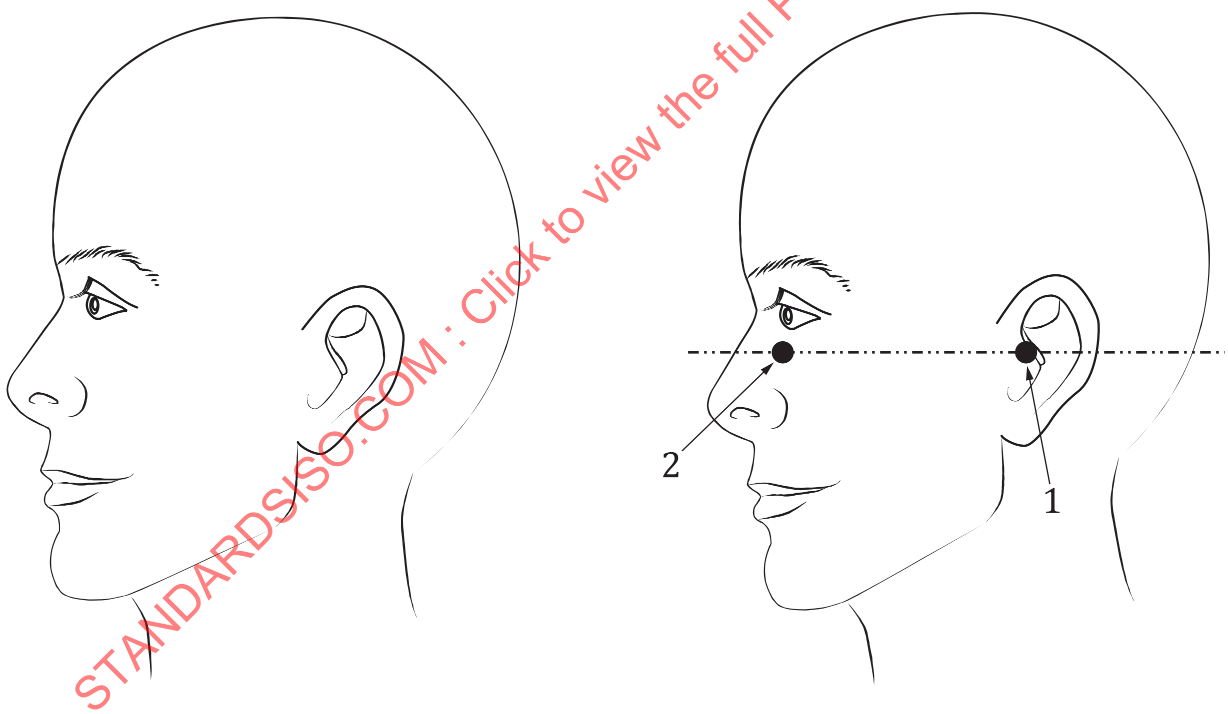
NOTE 2 Anatomical landmarks can be specified by using a coordinate notation function provided by 3-D scan data processing software. The positions of anatomical landmarks in the *x*, *y*, *z* coordinate system can be saved in a separate ASCII file (examples of file extension include .txt and .asc).

NOTE 3 Anatomical landmarks can be automatically or semi-automatically estimated by using geometry methods,[6],[16],[21],[23],[37],[38] template registration methods,[7],[22],[30] and/or machine-learning methods.[26],[34],[45]

## 5.5 Alignment of mesh coordinates

A 3-D human body mesh should be aligned based on anatomical landmarks by applying rotation to make a set of vectors connecting designated landmarks parallel to the *x*-, *y*- or *z*-axis of the 3-D coordinate system, then applying translation to place a particular part of the human body at the origin of the coordinate system.[36] The mesh alignment operation is of use to unify the orientation of all scans when creating a 3-D scan database.

NOTE The head can be aligned to the Frankfort horizontal plane that passes through the left and right tragions (notch above the tragus) and the left and right infraorbitales (inferior margin of the orbit) (see Figure 15).




**a) Before** **b) After**

**Key**

1 tragion

2 infraororbitale

**Figure 15 — Alignment of the head to the Frankfort horizontal plane**