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Information technology — 3D printing and scanning — Phantom-based evaluation methods for 3D printing modeling software

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Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*.

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 and www.iec.ch/national-committees.

Introduction

This document was developed in response to the needs of quality management of 3D printing and scanning technology by taking full advantage of information and communication technology (ICT).

3D scanning is the process of scanning a real-world object or environment to collect data on its shape and possibly its style attributes. The main purpose of 3D scanning is for generating high-precision digital 3D models by non-destructive, 3D scanning of internal and external geometries.

A 3D scanner can be based on many different technologies, each with its own purposes and targets, limitations, and advantages. There can be many limitations in each type of target object that will be digitized. For example, optical technology can encounter many difficulties with dark, shiny, reflective, or transparent objects. Another example is the use of computed tomography (CT) scanning, structured-light 3D scanners, and LiDAR technology, which highlights the need for non-destructive internal scanning methods to generate digital 3D models.

Despite the rapid growth of 3D scanning applications, the accuracy, precision, and reproducibility of 3D models generated from 3D scanned data have not been thoroughly investigated. When scanned data are used for 3D printing, their accuracy and precision are critical. Inaccuracies may arise during imaging, segmentation, postprocessing, and printing. The overall accuracy, precision, and reproducibility of 3D printed models are influenced by the cumulative errors introduced at each step in the model creation process.

For the continued expansion of 3D printing applications, it is necessary to review and evaluate the various factors in each step of the 3D model printing process that contribute to 3D model inaccuracy, including the intrinsic limitations of each printing technology.

— In this context evaluation of the overall process of data processing is critical.

— For minimization of cumulative errors of 3D printing life cycles using 3D scanned data, the initial error should be assessed and corrected.

— The assessment methods of 3D scanned data for 3D printing are essential.

Establishing a reliable and practical evaluation method for 3D modelling software is crucial for ensuring the quality and dependability of 3D models used in 3D printing. Standard CT performance evaluation phantoms and existing phantoms make evaluating the performance of 3D printing modelling challenging. A dependable and practical approach to evaluating the performance of 3D modelling software for 3D printing is essential and would benefit a wide range of stakeholders, including developers of 3D modelling software, manufacturers, and researchers. A phantom-based evaluation method can provide a reliable and practical way to evaluate the performance of 3D modelling software in the context of 3D printing. This would serve as a valuable tool for assessing the quality and dependability of 3D modelling software, which is crucial for ensuring the precision and safety of 3D printing applications.

This document proposes evaluation methods for 3D modelling software that use CT phantoms to assess quality enhancement and error minimization in 3D printed model.

Information technology — 3D printing and scanning — Phantom-based evaluation methods for 3D printing modeling software

1 Scope

This document defines an evaluation procedure and evaluation methods for assessing the accuracy and precision of 3D modelling software for designing 3D printing models using phantoms.

This document is not intended to evaluate the 3D-printed product itself.

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/ASTM 52920, *Additive manufacturing — Qualification principles — Requirements for industrial additive manufacturing processes and production sites*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions 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/

3.1.1
assessment
action of comprehensively evaluating the target entity based on documented criteria for a specific purpose

Note 1 to entry: Such purposes can include determining acceptance or release of the target entity.

[SOURCE: ISO/IEC 25040:2024, 3.1]

3.1.2
evaluation
systematic determination of the extent to which an entity meets its specified criteria

Note 1 to entry: The entity can be an item or activity.

[SOURCE: ISO/IEC 25001:2014, 4.1, modified — Note 1 to entry has been added.]

3.1.3
measure,noun
value described using a numeric amount with a scale or using a scalar reference system

Note 1 to entry: When used as a noun, measure is a synonym for physical quantity.

[SOURCE: ISO 19136-1:2020, 3.1.41]

3.1.4
phantom
reference object that is scanned to assess the accuracy and precision of the scanning device

Note 1 to entry: A phantom can be used for the definition of a quantity and made of artificial material (e.g. ICRU tissue) or for the calibration and then be made of physically existing material; see ISO 29661:2012, 6.6.2 for details.

Note 2 to entry: A phantom can be used for the scattering and absorption properties of the human body for a given ionizing radiation; see ISO 12749-2:2022, 3.4.71 for details.

3.1.5
phantom attribute
measurable attribute that expresses a value of measurement unit

3.1.6
phantom element
part or all of a phantom that including the set of phantom attributes

3.1.7
process
set of interrelated or interacting activities that use inputs to deliver an intended result

[SOURCE: ISO 9000:2026, 3.1.8, modified — Notes to entry have been deleted.]

3.1.8
segmentation
process of separating the objects of interest from their surroundings

Note 1 to entry: Segmentation can be applicable to 2D, 3D, raster or vector data.

Note 2 to entry: Segmentation method is defined in ISO 13322-1.

3.1.9
validation
confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled

Note 1 to entry: The objective evidence needed for a validation is the result of a test or other form of determination such as performing alternative calculations or reviewing documents.

Note 2 to entry: The word “validated” is used to designate the corresponding status.

Note 3 to entry: The use conditions for validation can be real or simulated.

[SOURCE: ISO 9000:2026, 3.12.13]

3.1.10
3D model
3-dimensional model
data set that contains 3-dimensional geometric elements representing the real object

[SOURCE: ISO/IEC 23510:2021, 3.7, modified — The preferred terms "3-dimensional design model" and "3D design model" have been removed; the preferred term "3-dimensional model" has been added; in the definition, "object/part to be manufactured" has been replaced by "real object".]

3.1.11
3D modelling
3-dimensional modelling
method of creating a 3D model necessary for 3D replication and 3D printing

3.1.12
3D modelling software
3D modelling program
software or program that is specific to the solution of 3D modelling

3.2 Abbreviated terms

CT	computed tomography
DICOM	digital imaging and communications in medicine
DICONDE	digital imaging and communication in non-destructive evaluation
NDE	non-destructive evaluation
3D	three dimensional

4 Modelling phase considerations for quality control of 3D printing

4.1 General

4.1.1 Background

In the cases of using image data, such as CT, to manually or semi-automatically, or fully automatically create a 3D model of the area to be 3D printed, the process is quite different from using a well-designed 3D model for 3D printing. In this case, the quality of the 3D print is highly dependent on the performance of the 3D modelling software.

In general, the 3D modelling process of creating a 3D model for 3D printing from an image goes through the following steps: image acquisition and processing, image segmentation, and 3D construction. Each step requires precise and accurate processing by modelling software for 3D printing, and there is currently no evaluation procedure or method to assess this.

4.1.2 Related works

a) Computer-aided design (CAD): 3D printing often requires a CAD model as input, which is ‘sliced’ into 2D layers and sequentially printed to form the 3D object. Defects in 3D printing can lead to dimensional deviations between the 3D CAD model and the physical printed part.

b) Model-based definition (MBD): MBD, sometimes called digital product definition (DPD), is the practice of using 3D models within 3D CAD software to define individual components and product assemblies. In MBD, it is possible to capture the dimensions, tolerances, notes, symbols, surface finishes, and other information that define components and products in the model, as opposed to a traditional 2D drawing.

c) 3D reverse engineering: this is the process of creating a digital 3D model from an existing physical object. Annex C provides typical applications of 3D reverse engineering for part repair and remanufacturing.

d) Impact on image registration algorithms: the heterogeneity observed in 3D printed phantoms affects the validation of image registration algorithms.

4.2 Workflow and product quality

ISO/IEC 3532-1 describes the workflow for generating 3D models and printing from scanned data, as well as the associated requirements. Figure 1 shows how the major phases defined in ISO/IEC 8803 can be classified into three task units. It also shows the 3D printing quality lifecycle and how quality measures can be related to the overall workflow.