FINAL DRAFT
Technical Report

ISO/DTR 24464

Visualization elements of digital twin — Visualization fidelity

ISO/TC **184**/SC **4**

Secretariat: **ANSI**

Voting begins on:
2024-09-27

Voting terminates on:
2024-11-22

This draft is submitted to a parallel vote in ISO and in IEC.

Reference number
ISO/DTR 24464:2024(en)

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Foreword

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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 documents 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).

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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 184, *Automation systems and integration*, Subcommittee SC 4, *Industrial data.*

This second edition cancels and replaces the first edition (ISO/TR 24464:2020), which has been technically revised.

The main changes are as follows:

— the title is changed;

— a three-elements architecture is added;

— this document focuses more on fidelity among visualization elements.

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

This document analyses the visualization fidelity among the visualization elements of a digital twin system. Since digital twin (DTw) is a new technology, various definitions are being proposed in the sector as a whole, so they collide with each other, and cross-reference is underway at the same time. This document analyses the element technologies and the properties that make up the DTw system, it also attempts to reveal the nature of the DTw, and focuses on visualization elements. This is expected to further solidify the identity of DTw, reduce confusion and consequently help further spread the use of DTw technology.

Visualization elements of digital twin — Visualization fidelity

1 Scope

The content of this document is divided into two parts.

— This document analyses the overall configuration of an industrial digital twin system, and proposes a three-elements architecture, focusing on the twinning interface between the physical twin (PTw) and industrial digital twin (iDTw).

— The characteristics, and the visualization elements and visualization fidelity of iDTw are analysed.

This document:

a) analyses the twinning interface between the PTw and iDTw;

b) proposes a three-elements architecture;

c) analyses the visualization element and its fidelity, which is a key component of the interface among the three-elements architecture;

d) analyses the elements that constitute an iDTw system to understand the unique properties of iDTw;

e) explores the differentiation from cyber physical systems (CPS) or augmented reality (AR), which are similar to existing concepts of iDTw.

This document excludes:

— applications of iDTw;

— implementation of iDTw.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain a terminology database for use in standardization at:

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

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

3.1
accuracy
closeness of agreement between a test result or measurement result and the true value

[SOURCE: ISO 3534-2:2006, 3.3.1, modified — Notes 1 to 3 to entry have been removed.]

3.2
asset
any item, thing or entity that has potential or actual value to an organization

[SOURCE: ISO/TS 15926-11:2023, 3.1.1]

3.3
asset administration shell
standardized digital representation of an *asset* (3.2)

[SOURCE: IEC 63278-1:2023, 3.1.2]

3.4
digital model
dataset to represent the *shape* (3.12) and any other desired characteristics for target synthetic model

[SOURCE: ISO 22926:2023, 3.1, modified — Term "digital anatomical bone model", Notes 1 to 2 to entry and the example have been removed.]

3.5
federation
community of domains

[SOURCE: ISO 12967-1:2020, 3.4.2]

3.6
fidelity
degree to which a model or simulation reproduces the state and behaviour of a real-world object or the perception of a real-world object, feature, condition, or chosen standard in a measurable or perceivable manner

[SOURCE: ISO 16781:2021, 3.1.4]

3.7
industrial digital twin
digital representation of a physical entity

Note 1 to entry: It represents the bit world rather than the atom world.

3.8
industrial digital twin system
compound model composed of a *physical twin* (3.10), an *industrial digital twin* (3.7), and a *twinning interface* (3.15) which is used for state *synchronization* (3.13) between two twins

3.9
level of detail
alternate representations of an object at varying fidelities based on specific criteria

[SOURCE: ISO/IEC 18023-1:2006, 3.1.8]

3.10
physical twin
object which exists in the real world

3.11
real time
guarantee response within specified time constraints

Note 1 to entry: Often referred to as “deadlines”.

3.12
shape
form of an object or its external boundary, outline, or external surface, as opposed to other properties such as colour, texture, or material type

3.13
synchronization
joining up or handshaking of multiple processes at a certain point, to reach an agreement or commit to a certain sequence of action

3.14
twinning
pairing or union of two similar or identical objects

3.15
twinning interface
mediator which allows mutual augmentation between *iDTw* (3.7) and *PTw* (3.10)

3.16
visualization
rendering of an object, situation or set of information as a chart or image

[SOURCE: ISO/IEC TS 5147:2023, 3.1.15, modified — Note 1 to entry was removed.]

4 Abbreviated terms

AAS	asset administration shell
AI	artificial intelligence
AR	augmented reality
AWI	approved work item
CAD	computer aided design
CAE	computer aided engineering
CG	computer graphics
CPS	cyber physical system
DTw	digital twin
fps	frames per second
FPSO	floating production storage offloading
HiFi	high fidelity
HW	hardware
iDTw	industrial digital twin
IoT	internet of things
JWG	joint working group
LoD	level of detail
LRC	local RTI component
MAR	mixed and augmented reality
MEMS	micro electromechanical systems

MR	mixed reality
NP	new proposal
O&M	operation and maintenance
P&ID	piping and instrumentation diagram
PLM	product life cycle management
PPI	pixels per inch
PTw	physical twin
RAMI4.0	reference architecture model industry 4.0
RPM	revolution per minute
RTI	run-time infrastructure
SMRM	smart manufacturing reference model
SMRL	STEP module and resource library
STEP	standard for the exchange of product model data
SW	software
TTR	technology trend report
VR	virtual reality
WiFi	wireless fidelity
XR	extended reality

5 Needs of DTw visualization

5.1 Atom world and a bit world

The concept of the digital twin (DTw) can be elucidated through the paradigms of the atom world and the bit world. The atom, being the fundamental unit of matter, serves as the foundation for the real world. This realm, governed by traditional economic principles, is often referred to as the physical world, characterized by the tangible presence of materials. Within the atom world, the economy is predominantly influenced by three factors: land, capital and labour.

Contrastingly, the bit world represents the online domain, where the economic paradigm shifts significantly from that of the atom world. In this digital space, data are stored as bits which do not require physical space, and the processing speeds surpass those encountered in the atom world.

5.2 Visualization of big and small things

As man-made products, including ocean platforms, satellites, factories, power plants, and urban infrastructures, grow in size and complexity, the challenge of managing these entities escalates. Consequently, there is an expanding demand for the utilization of DTws to manage these large and complex products. Similarly, in the realm of micro-materials, such as DNA and micro-electro-mechanical systems (MEMS), digital models replicating real-world objects are increasingly employed for planning, designing, producing, operating, monitoring, and maintaining these materials. Nonetheless, digital models, whether for macro or micro-scale applications, are often simplified or idealized versions of their physical counterparts, leading to inherent limitations.

The absence of visualization technologies raises questions about the practical value of a constructed DTw. This paradox underscores the critical importance of visualization capabilities. Visualization technologies, including video, are becoming increasingly vital in accurately simulating real-world scenarios with DTws.

5.3 Visualization of big data

With advancements in the internet of things (IoT) and sensor network technologies, an increasing volume of operational data are being digitized and stored through the internet and sensor devices, thus contributing to the formation of substantial big data assets. Figure 1 illustrates the process in which operational data, gathered via edge computing devices like smartphones, is archived and leveraged as big data within cloud computing infrastructures.

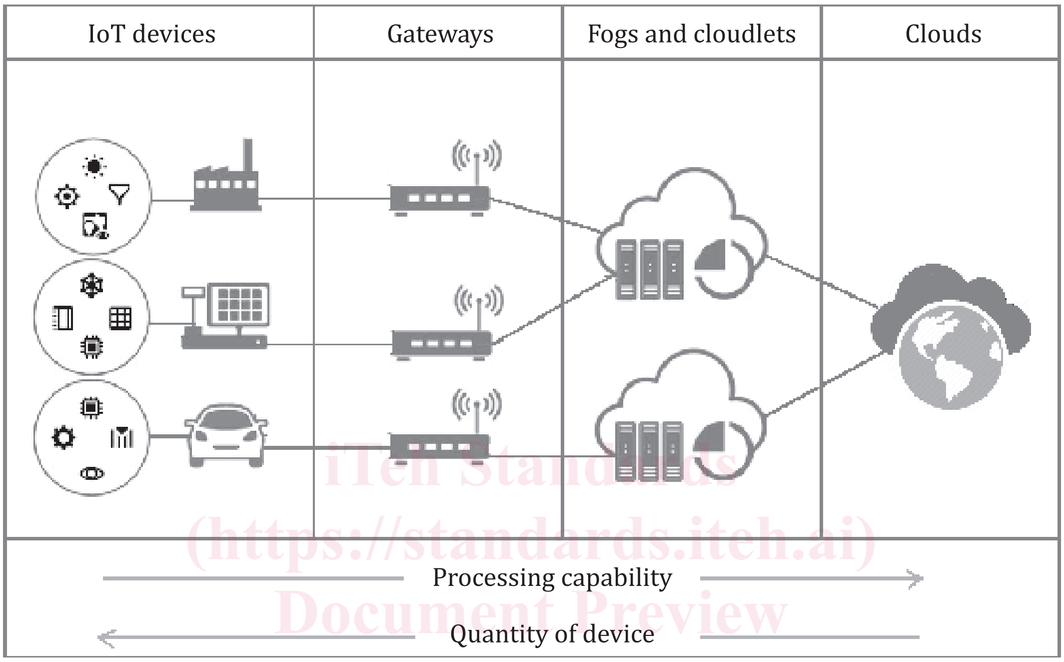

Figure 1 — IoT produces big data[29]

The sheer volume of this big data surpasses human analytical capabilities, heralding new horizons as artificial intelligence (AI) is deployed for its analysis. With big data integrated into digital assets and constructed as DTws, the fidelity in mirroring real-world scenarios surpasses that of traditional digital models.

The utilization of computer graphics (CG) for the visualization of big data has been established for quite some time, notably in applications such as climate modelling with supercomputers, biological cell or chemical modelling, and the interpretation of simulation outcomes via digital product models, including automobiles. These scientific visualization techniques pivot on CG rather than mere numerical calculations (Figure 2). The simulation outcomes, represented as numbers and compiled into big data, gain interpretative clarity through the application of AI and/or visualization techniques.

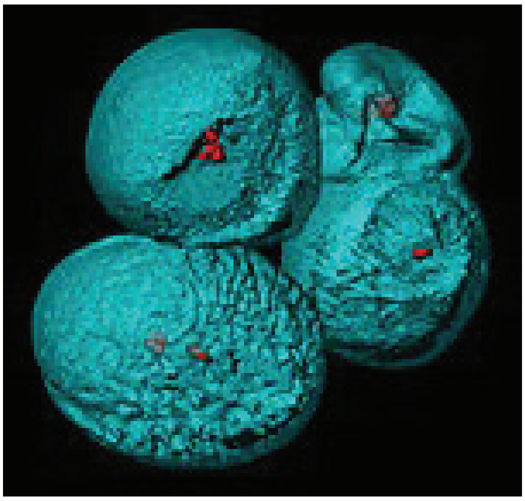

Figure 2 — Scientific visualization [39]

5.4 Visualization fidelity of the twinning interface

As depicted in Figure C.5 and Figure 3, the industrial digital twin (iDTw) system is composed of three core elements: the physical twin (PTw), the iDTw, and the twinning interface (see also Clause 6). This document primarily addresses the twinning interface that facilitates interaction between the PTw and iDTw, focusing on the standardization of visualization fidelity that is either shared or integrated between the PTw and the iDTw.

6 Three-elements architecture of the iDTw system visualization

6.1 General

As the interest in DTw grows, the introduction of varied definitions and architectures for DTws has led to confusion. To address this issue, formal concept analysis, as introduced in D.1, serves as a useful tool. It is important that the definition of an entity-of-interest is grounded in its properties.

In numerous references, the term "digital twin" is often equated with a digital replica. However, this document adopts the three-elements architecture based on the definition provided by Michael Grieves, who is credited with the concept of the DTw. The selection of terminologies are further explained in Annex B.

The iDTw system is characterized by a three-elements model, as illustrated in Figure 3, encompassing the PTw and the iDTw, both of which are integrated via the twinning interface. This model is collectively referred to as the "iDTw system". Annex E outlines a series of use cases that are applicable to the three-elements model.

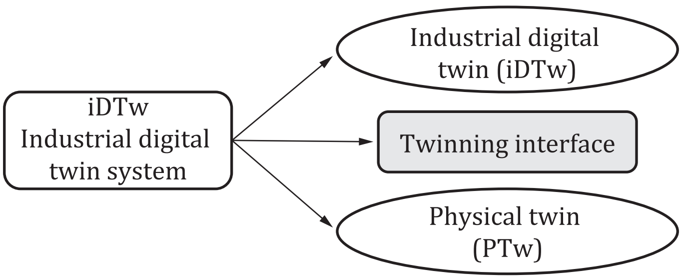

Figure 3 — Three-elements architecture of the iDTw system

6.2 Component technologies of DTw visualization

Drawing from the model proposed by Dr. Michael Grieves and the associated three-element architecture, the technologies integral to DTw visualization are delineated in Figure 4. Given the complex nature of DTws, capturing all component technologies within this document proves challenging. Thus, the focus is narrowed to the visualization aspects, which are systematically categorized. The various definitions of DTw are grouped and presented in Table A.1.

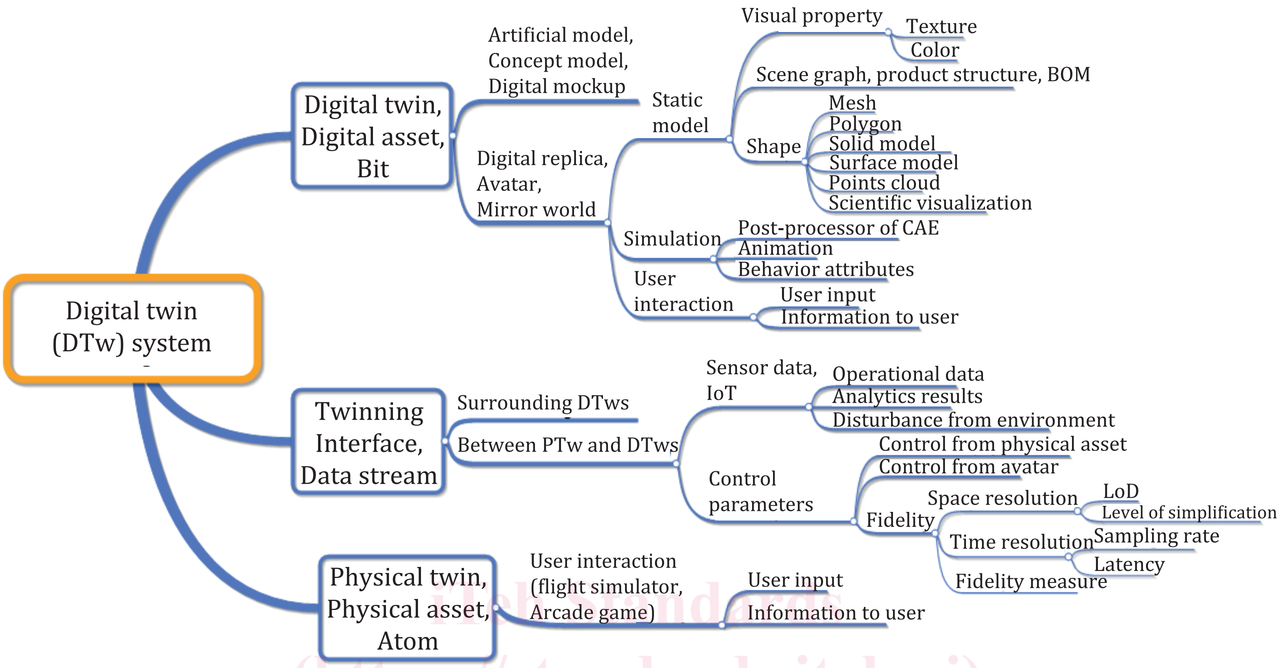

Figure 4 — Component technologies of DTw visualization

A substantial portion of the over 600 SMRL (STEP module and resource library) data models or product models (schemas) can be identified as components integral to DTws. The SMRL serves as the foundation for the STEP standard (ISO 10303 series), which encompasses not just design models but also those pertinent to production or manufacturing, including models dedicated to visualization purposes. For instance, the visual presentation aspect is specifically addressed in ISO 10303-46:2022, C.7.

6.3 Comparison with existing architecture

To explain the characteristics of the three-elements architecture, a comparative analysis with pre-existing architectures is conducted. Figure 5 illustrates the architecture outlined in the ISO 23247 series juxtaposed with the three-elements architecture detailed in this document. Within the scope of the ISO 23247 series, DTw applications, DTw, and certain aspects of the communication layer with physical devices are designated as "DTw for manufacturing". Whereas the present document classifies observable elements under PTw, and the communication layer is aligned with the twinning interface. It is noteworthy that "applications of DTw" are excluded from the iDTw system architecture as defined in this document.

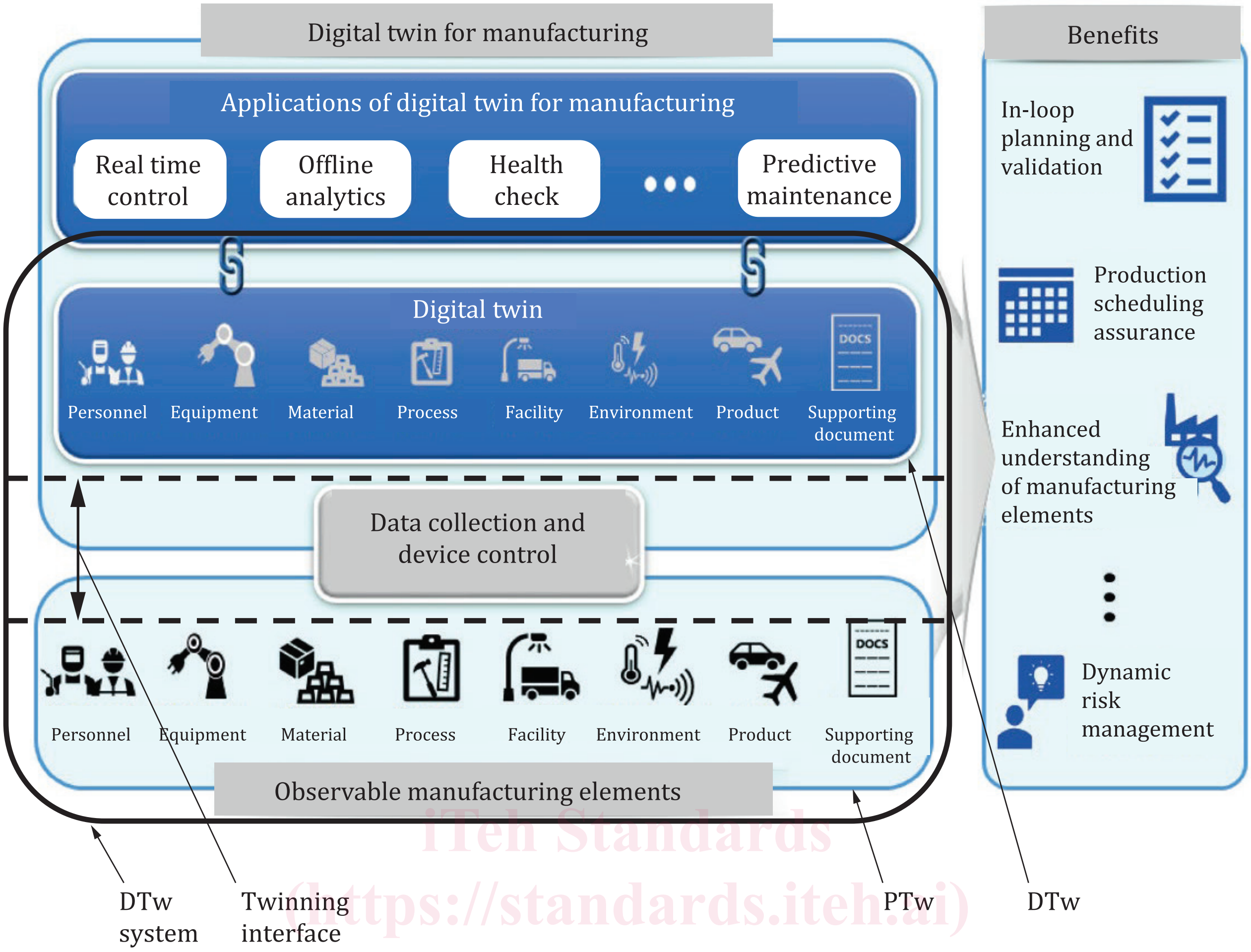

Figure 5 — Comparison with the ISO 23247 series

Figure 6 presents the reference architecture of the DTw as cited in Reference [16]. The components enclosed within the red box are indicative of the "iDTw system" as conceptualized within the three-elements architecture of this document. The real-world entity (RWE), which encompasses both a physical model and conceptual models or software (SW), aligns with the PTw as defined in this document. The real-digital gateway (RDG) is equivalent to the twinning interface outlined herein.