Visualization elements of digital twins

ISO/TC184/SC4/JWG16

2019-07-28

Soonhung.Han @kstep.or.kr
Contents

- Big data and Scientific viz.
- Digital Twins
  - Definition
  - Core technologies
- Difference from AR or CPS
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- Fidelity
- Viz. elements of DT
Big data drives AI and Digital Twin

Operational data from edge computing

https://www.oss.kr/info_techtip/show/95f45eef-d095-4fee-a161-bb64b3bc7895
Methodology of quickly and effectively displaying scientific data.

Once a computer experiment has been performed, the results must be interpreted.

Statistics can provide insights, it is difficult for the human to comprehend large volumes of numbers. (Big data)

Visualization techniques can interpret large data sets, providing insights that might be missed by statistical methods.
Industry 4.0 from wiki

1st: Mechanization, water power, steam power
2nd: Mass production, assembly line, electricity
3rd: Computer and automation
4th: Cyber Physical Systems

Mechanical
Electrical
Computer
Telecommunication (Smart phone, 5G)
Digital Twin
Digital Twin

Editors:

Sangkeun YOO (lobbi@etri.re.kr, KATS/ETRI)
Yuhang CHENG (chengyh@cesi.cn, SAC/CESI)
Digital Twin from Deloitte

Definition
- an evolving digital profile of the historical and current behavior of a physical object or process

Core technologies
- 1) sensors and actuators
- 2) integration
- 3) data
- 4) analytics 5) DT
Digital twins

Physical asset  Avatar

https://igotoffer.com/blog/digital-twin/
Definition of DT (digital twin)

- DT = tangible Asset + Avatar
  - Separation of two twins

- DTs = Physical + Avatar

- Digital Twins 쌍둥이 = Physical Twin 兄 + Cyber Twin 弟
  - Twins are two offspring produced by the same pregnancy: 1 egg, 2 egg
Physical asset (real world) → Realtime interface → Digital twin (virtual world)

- Big data
- Operational record
- FMEA
- FEA
- CAD model

status → control
Human Digital Twin

- Knowledge acquired with industrial equipment now being applied to humans

GE Healthcare
http://www.gereports.com/these-engineers-are-building-the-industrial-internet-for-the-body/

Lifecycle of DT
Digital (virtual) ➔ Physical ➔ Connected twin

Continuous improvement with the Digital Twin

- Digital Twin Product
- Digital Twin Production
- Digital Twin Performance

Insights from performance with MindSphere

- Verification
- Virtual production
- Validation
- Real production
- Commissioning
- Automation
- Ideal delivery
- Real product

Continuous improvement

Collaboration platform: Teamcenter

Unrestricted © Siemens AG 2017
Page 12  December 15, 2017

siemens.com/innovation

Difference from AR?

- Avatar vs. Digital twin
- DT = AR + IoT?
- Realtime operational big data
  - Data engineering
  - Stochastic engineering vs. Deterministic engineering
  - Uncertainty
- Computer simulation
  - Accident, performance, cost
  - Simulation game
Smart home, Smart city, (smart) Google Earth

CPS

https://www.designworldonline.com/big-future-for-cyber-physical-manufacturing-systems/
Difference from CPS?

- (realtime) Connection between twins
- Fidelity issue: Google Earth
I4.0 terms in the context of a three-layer model of Cyber-Physical-Systems (CPS)

- **Asset Administration Shell (2+3):** logical set of information and I4.0 interfaces of an asset. The whole structure is accessible via the I4.0 Infrastructure. This term is a synonym to the digital twin in a future, fully enhanced version.

- **The Administration Interface** comprises I4.0 compliant interfaces
  - No monolith: partial elements for role/type-instance/real world aspects.
  - No DLL, but platform independent
  - Provides standardized but also proprietary services and properties
  - Is associated to one or more assets and is able to moderate their communication via proprietary interfaces
  - Contains references to relevant data

- **A data-object contains data related to an asset**
  - A digital representation of an intended real device
  - It is the virtual representation of an asset in the I4.0 network.
  - It comprises requirements, assurances, typeinformation and instance data (like CAD, simulation model, function block networks, manuals, firmware, etc.) as well as services.
  - It can be updated via the Administration interface: realtime data, historical data, parameters for example.

- **The Asset is ...**
  - a valuable physical or non-physical entity.
  - a resource for the fulfillment of physical services.
  - a proprietary device: it contains proprietary properties and interfaces
  - an Industrie 4.0 Device: provides access to the device via the administration interface

- **Industrie 4.0 Component (1+2+3):** an asset combined with its Asset Administration Shell.
Levels of reality

- **Fidelity**
- **LoD (level of detail)**
- **Quality of synchronization**
  - realtime
  - precision
- **Shape and behavior**
  - How to visualize
Fidelity, LoD (level of detail)

Manufactured product

Design model

Points cloud
Fidelity

Can a computer simulation replace physical experiments?

- Car crash simulation
- Underwater explosion
- FSI (fluid structure interaction): FEM + CFD
- CFD: BEM (boundary element method). SPH (smoothed particle hydrodynamics). Molecular dynamics
Fidelity measure

- Texture map. Motion texture
- Resolution:
  - DPI of printer. Points cloud of a building
- Realtime sensor data from every leaf of Toulouse?
- Need a measure:
  - Shape similarity measure.
  - Image search engine
  - STEP model search
### Model Classification

*(plant industry, LoD)*

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Example (Valve)</th>
</tr>
</thead>
</table>
| **1** Symbol-level model  
(basic design stage, send to manufacturer) | • Simple model (3-dimensionalized symbol from P&ID)  
• Model in default libraries (known as catalog model) provided by a PlantCAD system. | ![Image 1](image1.jpg) |
| **2** Production model  
(production design stage of plant) | • Model that plant manufacturer re-models based on vendor-package (collection of 2D drawings, simplified symbol model) of equipment  
• The product model which is suitable for plant manufacturer | ![Image 2](image2.jpg) |
| **3** Handover model  
(reconstructed model from scanned data) | • Model that plant owner or operating company requests  
• Has different LOD depending on the requests | ![Image 3](image3.jpg) |
| **4** Scanned model (during or after construction) | • A points cloud model from 3D scanning during or after manufacturing or construction of the plant  
• It shows additional material such as insulation material surrounding the equipment | ![Image 4](image4.jpg) |
| **5** Detailed model from manufacturing (Vendor) | • Detail model of vendor for producing the equipment  
• Contains all (geometric/non-geometric) information about the product e.g. internal geometric information as well as detailed surface information  
• Due to security issues, only vendors have the model | ![Image 5](image5.jpg) |
What to do

♦ STEP model ~ Product digital twin
♦ STEP model viz. of JWG16 ~ viz. of Product digital twin
  ■ Product can be a man-made thing: Asset, parts, facility

♦ PWI: TR for Digital Twin viz.
<table>
<thead>
<tr>
<th>표준제정팀 Standard project team- Digital Twin</th>
</tr>
</thead>
<tbody>
<tr>
<td>ChangShin Design Lab, 대표 CEO</td>
</tr>
<tr>
<td>Samsung Heavy Ind., 센터장</td>
</tr>
<tr>
<td>PartDB Co., 연구원 Researcher</td>
</tr>
<tr>
<td>ACS Co., 부사장 Cofounder &amp; CTO</td>
</tr>
<tr>
<td>ETRI, 책임연구원</td>
</tr>
<tr>
<td>hyundai-steel.com, 차장</td>
</tr>
<tr>
<td>3D PDF Consortium, Researcher</td>
</tr>
<tr>
<td>Toyama Prefectural University, Professor</td>
</tr>
<tr>
<td>PERA Corporation Ltd., Researcher</td>
</tr>
<tr>
<td><a href="http://www.wiz.top">www.wiz.top</a>, Researcher</td>
</tr>
<tr>
<td>EDF, PLM Team leader</td>
</tr>
<tr>
<td>Boost Co., CTO</td>
</tr>
</tbody>
</table>
Double Vision: Using ‘Digital Twins’ To Pair Virtual And Physical Worlds
Goldman Sachs

Being able to “see it before you build it” has long been a dream of manufacturers, but only recently has technology advanced to make this possible.

Digital twin: Making your asset smarter with the digital twin
DNV GL - Digital Solutions

Central to our next-generation offering, and supporting an ecosystem of asset-centric engineering applications, is the
Digital twin videos

Siemens
Factory operation
https://www.youtube.com/watch?v=OVGbT6Wx8SU
Machining twin
https://www.youtube.com/watch?v=D51dGwkxs2k
Digital enterprise
https://www.youtube.com/watch?v=ePZheUvsH0w

GE Ocean wind power
https://www.youtube.com/watch?v=3Y1InF4_pKY
Autodesk University
https://www.youtube.com/watch?v=G5jYyB2bZ6k
KAIST
https://www.youtube.com/watch?v=2cFXDI_8RUA
Laser Scanning with AVEVA LFM

AVEVA LFM • 조희수 6.5만회 • 5년 전

AVEVA's goal is that for every physical asset, there should be a digital equivalent. Capturing the as-built condition of an asset...
Augmented Reality Definition

https://www.realitytechnologies.com/augmented-reality/

An enhanced version of reality where live direct or indirect views of physical real-world environments are augmented with superimposed computer-generated images over a user’s view of the real-world, thus enhancing one’s current perception of reality.
Industry 4.0 from wiki

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4th: Cyber Physical Systems
Augmented reality (AR) from wiki

A real-world environment where the objects that reside in the real-world are enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory.
avatar

- [https://dictionary.cambridge.org/dictionary/english/avatar](https://dictionary.cambridge.org/dictionary/english/avatar)

- an image that **represents you** in online games, chat rooms, etc. and that you can move around the screen

- a character or creature that you create to **represent yourself** in a computer game, on the internet

- especially in **Hinduism**, a god who appears on earth as a person
INDUSTRY 4.0
TRANSFORMING INDUSTRIES AND INNOVATION INFOGRAPHIC

INDUSTRY 1.0
1784
Mechanization, steam power, weaving loom

INDUSTRY 2.0
1870
Mass production, assembly line, electrical energy

INDUSTRY 3.0
1969
Automation, computers and electronics

INDUSTRY 4.0
TODAY
Cyber Physical Systems, internet of things, networks

http://www.imm.dtu.dk/~jbjo/cps.html
Core tech of Ind. 4.0

- AI
- Digital Twin
- CPS
- 3D printing
- Standards
- Cybersecurity
- Big data
- Augmented reality
- Cloud computing
- Autonomous robots
- System integration
- Internet of Things
- Simulation
- Additive manufacturing

https://www.isa.org/intech/20160601/
https://www3.nd.edu/~dwang5/courses/spring17/

University of Notre Dame
Structure of Asset Administration Shell
http://acplt.github.io/openAAS/AssetAdministrationShell.html

I4.0 component Maps the runtime data of the Asset in the information world

Source: DIN SPEC 91345:2016-04
Administration shell for digitalization
ISO/IEC JTC 1

Information technology

Secretariat: ANSI (United States)

Document type: Other document (Defined)

Title: Technology Trend Report on Digital Twin

Status: This document is circulated for review and consideration at the May 2019 JTC 1 Plenary in Hawaii.

Date of document: 2019-03-26

Source: SWG 7 Convenor
https://www.youtube.com/watch?v=ejuq1s2ygw4&feature=youtu.be

KAIST PhD thesis 2015
Keywords of digital twins

- Industry 4.0
- Digital twins
- Physical asset
- Sensor data
- IoT
- Operational Big data
- Data analytics
- Monitoring
- Predictive maintenance
- Realtime
- Digital model
- Simulation
- Behavior
- Visualization
- XR (VR, AR, MR)
https://www.unity.de/en/services/digital-twin/
Digital twin timeline

Digital product → Digital production → Physical production → Physical product

Parameter adjustment/Predictive maintenance

Diagnostics/monitoring → Data analytics

IoT → Operational data

Actuator → Sensor data
Automatic reconstruction of KAIST campus
Figure 1. Manufacturing process digital twin model


Source: Deloitte University Press.
Points cloud

Mesh model