Closing the loop from Virtual to Real and Back with 3DEXPERIENCE Twins

Dr. Tom-David GRAUPNER
Dassault Systemes Deutschland GmbH
tgq@3ds.com
**Contents**

- Digital continuity
- Classical Feedback to design
- Learning from the field with IIOT*
- Digital Twins powered by Dassault Systemes’ Platform

**Closing the loop from Virtual to Real and Back with 3DEXPERIENCE Twins**

* IIOT = Industrial Internet of Things
Challenges Today in Industrial Equipment

- We currently **cannot visualize the latest state** of our installed base with all vital product specifications.

- This means have to **undertake a series of tasks** to understand how our products are currently standing in the field. This is partly possible with **tedious work** and sometimes not at all.

- That’s why we would like to have **more transparency** and this not only until our product is installed at the customer site but also **thru its complete lifecycle**.
Today, everything is well structured and under control?
Ambitions for the future in Industrial Equipment

- **Analytics**:
  - Descriptive: What happened?
  - Diagnostic: Why did it happen?
  - Predictive: What will happen? (Model-based with Digital Twins)
  - Prescriptive: What should I do? (Real-time IoT data capturing, simulation & execution)

- **Human Input**
  - Decision Support
  - Decision Automation

- **Data**: Action

Source: Gartner (September 2013)
How can **model-based** development methods, **smart manufacturing**, the Industrial Internet of Things (**IIoT**) and **Industry 4.0** help promote product development, manufacturing and after-sales services?

The Answer: Digital Twins!
What is the idea of 3DEXPERIENCE Twins?

- **Invent**
  - **Virtual (3DEXPERIENCE Twin)**
  - **Improve**: Data Enriched

- **Run**
  - **Virtual Designs Optimize the Consumer Experience**
  - **V2R**: Virtually Validated
  - **Real**: Real life Insights enrich the Design
  - **Learn**: Continuously Updated

- **Real**
  - **Digitally Augmented**

**3D**

- **V+R**: 3DEXPERIENCE™ Twin
3DEXPERIENCE
Core Capabilities

DATA SCIENCE
Big Data / Analytics / Machine Learning

SCIENCE
Modelling / Simulation

COLLABORATION
globally, in real time
Unique levers to build **Digital Twins**

More than **500 Apps** on **3DEXPERIENCE**

- **#1 Digitally Connected**
- **#2 Model Based**
- **#3 Data-Driven**
- **#4 Virtual +Real**
#1 Digitally Connected vs. Electronically Connected
#2 Model Based in Topology Optimization

Arc Angle

Pocket Depth

Wall Thickness

Rear Radius

And more...
#3 Data-Driven - Using the example of Dashboarding

Bob log in to the 3DEXPERIENCE platform to access his project Dashboard
#4 Virtual+Real – Linking the Virtual with the Physical

Test Engineering

- Optimize Physical Tests by first designing & simulating them Virtually
- Plan and capture information of physical tests: on what, where, why, and how
- Increase testing confidence, accuracy, precision and reduce overall testing effort
What is a Digital Twin?

- A Digital Twin is a virtual model of a process, product or service.
- It needs to represent specific aspects of physical objects which are relevant for the user(s), like working state, shape and structural behavior.
- The pairing of the virtual and physical worlds allows:
  - to analyze data, monitor systems, simulate real world conditions, respond to changes, improve operations, before implementation.
- The concept is covers all (past, current and future) configurations during the entire life cycle.

⇒ In Short: 3DEXPERIENCE provides the capability to efficiently create Digital Twins.
3DEXPERIENCE Twin is the further development of a Digital Twin, it combines Engineering and Data Sciences

<table>
<thead>
<tr>
<th>Modeling approach</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data-driven Science</td>
<td>• Large number of variables</td>
<td>• Large amount of training data needed</td>
</tr>
<tr>
<td>(e.g. pattern recognition based on data w/o</td>
<td>• Complex, unstructured Data</td>
<td>• Limited extrapolation</td>
</tr>
<tr>
<td>knowing their meaning)</td>
<td>• Short calculation time (after training)</td>
<td>• Limited insights into underlying mechanism</td>
</tr>
<tr>
<td>Engineering Science - Model &amp; Simulation</td>
<td>• Limitation for extrapolation</td>
<td>• Depends on derivation of governing equations</td>
</tr>
<tr>
<td>(e.g. FEM, CFD, behavior models)</td>
<td>• Small amount of validation data</td>
<td>• Actual measurements parameters may not be part of the model (e.g. Audio, image, video)</td>
</tr>
<tr>
<td></td>
<td>• Storing insights of underlying mechanism</td>
<td>• Long calculation time for some simulations</td>
</tr>
</tbody>
</table>

Field Measurement (IoT data) Lab Measurement
User-defined Environmental Models
Training data generation Deviation control

3DX Twins

Actual Data
Predictive Model
Residual Processing
Prediction

Data-driven Predictive Model
Simulation Model
Ready for real projects?
Smart Closure Product Validation with Virtual Reality
Digital Twin for Robot-Assisted Durability Tests
After Sales Services in Industrial Equipment (IE)
Digital Twin for After Sales Services in IE | Initial Situation

WHAT

HOW

WHEN & BY WHOM

HOW MUCH

FOR WHOM

Execution

WHY
Digital Twin for After Sales Services in IE | Approach

Real Time Dashboarding with 3DEXPERIENCE for Field Engineers
Invisible & non-intrusive consolidation of enterprise data & IoT-field data

Enterprise System (SAP PLM)

Service Oriented Data Integration Layer

- SAP ERP
- Issue DB
- Spare Parts DB
- Workinstructions
- IoT-Field Data
Digital Twin for After Sales Services in IE | Demo
3DWorkbook for After Sales Services | New in R2019x
End-to-end Digital Twin in Industrial Equipment

Requirements-Management  Design Simulation Modeling Validation  Industrialization  Sales Configurator  Manufacturing  Installation  Maintenance Repair  Retrofit

Configuration (Portfolio / Dictionary / Variant / Evolution)
Change (Request / Order / Action)
Program / Project / Task / Tests
What’s Next

CAD > CAD

(Computer Aided Design > Cognitive Augmented Design)
Everyone talks about AI*, ML**, and IOT***

What has changed? More Computing **Power** x More **Data** x Smarter **Algorithms**

- **More Computing Power**
  - Moore’s Law (x2 comp. power each 18 month)
  - More Cloud Providers
  - More Smart Devices

- **More Data Generation**
  - Connected (Mobile) devices/objects/sensors
  - Social Media

- **More sophisticated Algorithms**
  - Image Recognition
  - Smarter Algorithms in e.g. Logistic

- Leads to more social diffusion/acceptance
- Leads to more Interaction between the physical and the virtual
- And to a tremendous acceleration of innovation

* Artificial intelligence
** Machine Learning
*** Internet of Things
The winner takes it all …

Digitale Herausforderungen treiben einen Keil zwischen etablierte Unternehmen und ihre Kunden

Erfassung von Informationen aus Social Media
Kundenspezifische Anpassung & Information

IOT Plattformen Economies of scale
The winner takes it all

Growing the business exponentially

Building an eco-system: Customers Partner

FORUM, 18. Oktober 2018
Be the one who gets followed, instead of the one who follows
Backup
Use Case

Global Cooling Systems manufacturer

The 3DEXPERIENCE® Company
Air Conditioning System Modeling

Functional 1D Modeling in Dymola based on the open Modelica modeling language

- Dymola model is based on TIL libraries
  - Realistic simulation
  - Multi refrigerant
  - Representation of multi-physics parameters
  - Representation of IoT sensors (room temperature, external temperature, evaporator coil temperature, compressor voltage)
  - External conditions scenario (weather, room occupancy, room size & thermic inertia…)
  - Control command (temperature regulation…)
  - Fault & errors
Fault-failure modeling in Dymola

Dymola Fan failure simulation

- Introduce a failure in the motor fan
  - Add a control law to reduce fan efficiency from 100% to 0% in 13 hours
  - Observe the effects on lot sensors measures
    - Variation of room temperature compared to evaporator coil temperature
    - Effect on the compressor voltage
  - Observe different time windows
    - During and after the failure (1 day)
    - After several days if the failure is not detected (3 days) Compressor is running to the max and should failed shortly after fan motor.
System modeling and Advanced Analytics

Contribution to efficient reliability model creation

- Capitalize unknown behavior
- Explain specific situation for diagnosis
- Supports feature engineering

Field Data to feed, train and optimize the Model

Systems Modeling with Dymola

Feature extraction

Model creation
Use Case
Predictive Maintenance

AS-IS: Customer Situation
• More than 1000 machines (all different) are running worldwide
• High maintenance costs
  • Costs of onsite maintenance: 1550 days of travel per year at customer site
  • Costs of Machines Downtime

TO-BE: Predictive Maintenance based on 3DEXPERIENCE Twin
• Decision aids tool based on MBSE (3D, Behavior,..)
• Actual data (difficult to obtain) replaced by data generated by the simulation
• Decision making from multi-source data (simulation, actual)
Customer Use Case : Merge data

Merge data from Virtual model and Real measurement and compare both of them. Human observation can be considerate like the first step for machine learning.
Customer Use Case: Machine Learning

Reference model (blue)
New entry (green)

Protocol

Tolerance corridors are the positive and negative deviations we can allow before we deem a result unacceptable.

Difference > 10 % ➔ anomaly
Tools & Applications for success
3DEXPERIENCE Platform Services and User-Interface

3DSwym
Social collaboration through communities.

3DSearch
Intelligent fuzzy search, re-use and re-purpose of intellectual assets.

3DPassport
Identity management and authentication across all apps.

3DNotifications
Deliver notifications from platform as well as apps.

3DPlay
Visualize, review designs and play experiences in 3D.

3DComments
Share your thoughts. Engage in discussion with peers.

3DDrive for Cloud
Secure file sharing on the cloud with 3DPassport.

3DCompass
Provide personalized and role-based access to all apps.

Roles
User assigned to multiple roles. Selection of a role displays apps required.

Apps
Intelligent launch of apps in context of the data.

3DDashboard
Subscribe to multiple feeds from the internet.
"Analytics builder" is an application that allows you to take all your data to dynamically analyze them to create new insight in a "self-service" mode.
Statistics and Predictive Analytics with ©BIOVIA “Pipeline Pilot”

- Access disparate (possibly complex) data locked in silos
- Automate scientific data analysis
- Explore, visualize and report results
Remove Unpredictability through Pattern Recognition with © DELMIA “Operational Intelligence”

Solution
- Quantification of variable influence by pattern recognition
- Knowledge formalization ready to be leveraged
- Suggest new optimized explanations and define rules
- Collection of rules to explain process performance deviations

Benefits
- Scrap rate reduction
- Rework reduction
- Increase productivity
- Quality prediction
Field Issue Intelligence Analytics with ©EXALEAD “CloudView”

Solution

▸ Unified investigative after-sales product issues analytics to search, compare, observe, and reconcile warranty claims, predictive peaks and public complaint and recall data
▸ Early trend detection and classification
▸ Early alerting system

Benefits

▸ Quality improvement: Weak signal detection & predictive analysis on multi source warranty databases, sensor, customer quality sources
▸ Cost Reduction: Product Performances Analytics on product usage data to find “over engineered” parts
In-Context Design Support with EXALEAD OnePart
EXALEAD PartSupply Community Service
Design Assistant in 3DEXPERIENCE CATIA
Advanced Design Assistant in 3DEXPERIENCE CATIA
Summary

► Digital twins have already reached a high degree of maturity – in all industries
► The basis is the provision of information in the required context – for all disciplines
► The value of digital twins is massively improved by capturing IOT field data – from product operation
► Data & Engineering Science enhance the twins predictivness – that’s key for real time applications
► A comprehensive digital thread can only be achieved by integrated product platforms – like 3DEXPERIENCE
Electro Mobility Startups selecting 3DEXPERIENCE
DS Value Engagement Model Phases

Value Assessment
- ROI Calculation
- Use Case role based
- S&SI Roadmap

Value Definition
- Use Cases, Processes,
  Demonstration, Test
  Scenarios

Value Commitment
- Services high-level
  proposal and/or Pilot

* ROI => Return of Investment
S&SI => EXALEAD Sourcing & Standardization Intelligence
Process => AS-IS processes currently in place to be digitized / improved
Summary of Customer Needs according to 3DX Twins

**3DEXPERIENCE Twin Project Objectives (Schindler)**

1. **Product Creation**
   “Speed through simulation – no quality issues at market entry”

2. **Sales & Marketing**
   “Provide customer with digital product information”

3. **Supply Chain**
   “Faster industrialization and cost reduction through simulation, planning and optimization”

4. **Assembly & Installation**
   “Make use of digital tools for elevator assembly or elevator installation”

5. **Maintenance**
   “Know before components fail and identify points for product improvements”
Digital Twin Showcase
3DEXPERIENCE Ambitions for a Model Based Enterprise

**Model-Based Program / Project Management**

- **Model-Based Sales & Operations planning**
  - supply vs. demand
  - Resources optimization
  - Production plans

- **Model-Based Product Architecture**
  - Modularity
  - Interfaces
  - Technical Configuration

- **Model-Based System Engineering (MBSE)**
  - System modeling
  - System simulation

- **Model-Based Materials & Formulations**
  - Material
  - Formulation

- **Model-Based Engineering**
  - Design in configured context
  - Knowledgeware
  - Digital & Functional Mock-Ups
  - PMI / FTA

- **Model-Based Testing**
  - Virtual and Physical Test Plan
  - Physical Samples to be tested

- **Model-Based Manufacturing Engineering**
  - Process modeling
  - Resources/Robots
  - Routings
  - Work instructions
  - Scheduling
  - Work orders

- **Model-Based Service Engineering**
  - Service BOM
  - Resources
  - Routings
  - Work instructions

**Model-Based Simulation / Optimization (FEM / CFD / Behavior / Ergonomics / Load balancing / Scheduling / What if scenarios)**

**Model-Based Change Management**

**Model-Based Configuration Management**
3DEXPERIENCE Ambitions for a Model Based Enterprise

Model-Based Program / Project Management

Model-Based Sales & Operations planning
- supply vs. demand
- Resources optimization
- Production plans

Model-Based Product Architecture
- Modularity
- Interfaces
- Technical Configuration

Model-Based System Engineering (MBSE)
- System modeling
- System simulation

Model-Based Materials & Formulations
- Material
- Formulation

Model-Based Engineering
- Design in configured context
- Knowledgebase
- Digital & Functional Mock-Ups
- PMI / FTA

Model-Based Testing
- Virtual and Physical Test Plan
- Physical Samples to be tested

Model-Based Manufacturing Engineering
- Process modeling
- Resources/Robots
- Routings
- Work instructions
- Scheduling
- Work orders

Model-Based Service Engineering
- Service BOM
- Resources
- Routings
- Work instructions

Model-Based Simulation / Optimization
- (FEM / CFD / Behavior / Ergonomics / Load balancing / Scheduling / What if scenarios)

Model-Based Change Management

Model-Based Configuration Management
How 3DEXPERIENCE Platform is addressing Industry Trends in Industrial Equipment – today and tomorrow

“"We offer a single **product backbone** data-driven with up to date holistic product data available across all group sites across all business units, all engineering disciplines, production, and service. Encompassing all possible **configured playable system models** ("Twins") that are to be **compared with field equipment data.**"

- Data – not file-driven
- For the entire company
- For all disciplines
- From first spec to retrofit
- Multiple Simulations
- Ready to close the loop
3DEXPERIENCE Platform Pillars

Data-driven

Model-based

3DEXPERIENCE Twin
Hybrid Prototyping with Force Feedback Device

Smart Hybrid Prototyping for early human centered System validation in Model Based Systems Engineering
Advanced Analytics | Predictive Maintenance

LEARN
Continuously Updated
VIRTUAL

System Model
(CATIA Systems / Dymola)

Functional + Dysfunctional Simulations

Features extraction
(Pipeline Pilot)

Data Science

Predictive

PredictMaint01
Multiple Category Model

RUN
Continuously Optimized
REAL

Diagnosis and optimization

Capitalize unknown behavior

Data Science

PPMP

IOT Gateway

37 Maintenance 7 Failure 8761 Time 35 Status

Data Science

Machine Learning, ..
Industrial machine / equipment

Sensor positioned on machine

Rexroth
Bosch Group

IoT Gateway

connection
Web protocol

Microsoft Azure

Application interface

IoT Platform - Cloud

Advanced Analytics

Filtered data by a data scientist

Smart data Application

3DEXPERIENCE Twin

3DCOM © Dassault Systèmes | Confidential Information | © Dassault Systèmes 2019 | ref.: 3DS_Document_2015
Advanced Analytics

Mathematics laws
Example: dynamic time warping, quantify difference between two data

Clustering algorithm

Machine Learning

Human observation

Smart Data Application

Processing

Index Data
3DEXPERIENCE Twins Business Values

▶ Boost Performance
  ▶ Reduce number of prototype creation & physical test
  ▶ First time right, every time
  ▶ Feedback loop to requirements results and improve specs

▶ Time to Market
  ▶ Reduce time to market
  ▶ Reduction of claims

▶ Field Operation Efficiency
  ▶ Downtime reduction through predictive maintenance
  ▶ Saved time when creating & updating tech doc
  ▶ Decrease resolution time for field incidents
  ▶ Increase spare part identification
Examples Bridgestone

- Demonstrate digital continuity from Requirement, to engineering up to simulation
  - Requirement and Program Management (including a short view of social audition)
  - Digital Continuity from Portfolio management to requirements, and up to an engineered tire (including automated process)
  - Digital Continuity from tire 3D definition to simulation (including DOE)
  - Qualification Process (Requirements and Test Plans)
  - Manufacturing BOM and BOP
3DEXPERIENCE Twin Project Objectives (Schindler)

Assembly & Installation
“Make use of digital tools for escalator assembly or elevator installation”

Supply Chain
“Faster industrialization and cost reduction through simulation, planning and optimization”

Sales & Marketing
“Provide customer with digital product information”

Product Creation
“Speed through simulation – no quality issues at market entry”

Maintenance
“Know before components fail and identify points for product improvements”
Industry Trends in Industrial Equipment

**INTELLIGENT CONNECTED SYSTEMS**
- Capture IOT data and interpret it
- Define, feed and play Digital Twins
- Prod. Develop. with Systems Engineering

**PRODUCTION OF ONE**

**PRODUCT AS A SERVICE**
- Modular Product Platforms & Configurators
- Transform to Service Business Model
- Create new service offerings
- Rapidly quote and execute

**DATA ECONOMY**
- New Customer Experience

**NEW CUSTOMER EXPERIENCE**
- Better understanding customers needs

**PRODUCTS = Intelligent Systems**