Digital Twin
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What is a Digital Twin?

1. A digital replica of a product or system, maintained as a virtual equivalent throughout the lifespan of the physical product.
2. A dynamic software model that uses sensors and other data to analyze its state, respond to changes, and improve operations.

How close is Digital Twin to its Physical Counterpart?

From weak correlation to almost exact design-time and runtime clone

Is Digital Twin for simple products or complex factories?

Application of a digital twin span from manufactured products, device, machines up to whole factories
Pairing of digital objects and physical objects pioneered by NASA in early days of space exploration.

Motivated by challenge of designing things that travel beyond ability to immediately see, monitor or modify them.

Objective was a complete digital model that can be used to operate, simulate and analyze an underlying system governed by physics.
Digital Twin in Energy Sector As data streams in, the twin evolves to reflect how the physical product has been altered and used and the environmental conditions to which it has been exposed.

Digital Twin in Maritime Sector virtual image of your asset, maintained throughout the lifecycle and easily accessible at any time. One platform brings all the experts together, bringing powerful analysis, insight and diagnostics.

Digital Twin in Power Plant Operations The digital twin essentially creates a digital model of the operations of an asset, say, a power plant and continually updates the performance model with feedback from real life operations.
Purposes of the Digital Twin

1. **Descriptive** – get visibility of your product, device, machine or factory
2. **Interrogative** – discover problematic areas
3. **Analysis and design** – design new generation of your system based on analysis
4. **Diagnostic** – get online diagnostics
5. **Predictive** – predict failures, downtimes, material shortage etc.
6. **Anticipatory** – perform corrective actions upfront
How to build a digital twin – factory
As vehicles get smarter and increasingly connected, operational data can be leveraged across the full lifecycle of the product with the help of a digital twin.

Real-time analysis of engine speed, air/fuel ratio, oil pressure, coolant temperature and other critical parameters can optimize efficiency, prevent breakdowns and elevate the driver experience. Additionally, insights gained from this data can guide the next generation of engine design and the smart manufacturing processes that build the connected engine.

An engine can become an innovation platform with the digital twin
How to build a digital twin – complex component

GOAL
=> Find explicit dependencies between input and output, hidden patterns
=> Have predictive models predicting outputs for new designs

WHITE BOX MODELS (tooling SPSS, R, Matlab)
1. Single variable correlations
2. Removing error measurements
3. Multiple variable correlations
4. Removing outliers and unimportant variables (e.g. Principal Components Analysis)
5. Develop linear regression models
6. Develop non linear regression models
How to build a digital twin – complex component

GREY BOX MODELS
1. Gradient boosted trees
2. Hybrid models
3. ...
4. Back explanation of key dependencies

FULLY BLACK BOX MODELS (Tooling TensorFlow, DL4J, Spark)
1. Deep neural networks (convolution, recurrent...)
2. Back explanation almost impossible 😞
Digital Twin at IBM


IBM Bluemix provide premium sw stack for digital twin

- **IoT platform** => management of devices, read data from sensors and interact through actuators
- **Cloud data services** => store huge amount of structured and unstructured data
- **Data Science** => analytical platform for analysing data and development of predictive models
- **Hyperscale computing**
- **Out of box analytics and AI services** => image recognition, speech recognition, pattern analysis etc.
Figure 1: Top Pressures to Improve Product Development

- Demand to launch products quickly (before competitors): 51%
- Market demand for higher quality / higher performance products: 48%
- Market demand for customized and complex products: 47%
- Market demand for lower cost products: 42%
- Compliance with regulations and / or industry standards: 34%

Source: Aberdeen Group, April 2017

Percentage of Respondents, n=197
Analyst Reports – Trends

Figure 1: The Best-in-Class Rely on the Digital Thread

- For product design: 53% Best-in-Class, 30% All Others
- For manufacturing processes: 55% Best-in-Class, 30% All Others
- For production: 57% Best-in-Class, 22% All Others

Percentage of Respondents, n=215

Source: Aberdeen Group, June 2017

Figure 2: Trending Adoption of the Digital Thread

- For product design: 53% Currently implemented, 26% Plan to implement
- For manufacturing processes: 55% Currently implemented, 32% Plan to implement
- For production: 57% Currently implemented, 30% Plan to implement

Percentage of Respondents, n=215

Source: Aberdeen Group, June 2017
New business models

Inversion of value of product and model

Changing the traditional sell model:
• Sell product + twin
• Sell product + “black box” service
  • Micro transaction each time accessed
• Open source digital twin
  • Basic model for free, pay to unlock features
New ecosystem

• Suppose you are a company that manufactures the engine for an engine for an automobile

• Your customer will have a digital twin for each of its automobiles

• They will expect you to deliver the engine along with the digital model that is an exact replica of the engine to plug into their digital twin

• Your engine includes component parts made by a supplier, who must deliver the part and its digital model to you.
Chosen IBM reference for digital Twin - Airbus
Chosen IBM reference for digital Twin - Airbus
Chosen IBM references - local

• **Automotive components** – virtual predictive model of engine components that are used by BMW, Porsche, Ferrari

• **High precision machinery** – virtual model of the factory that allows improving output quality, reducing leavings, predict outages

• **Chemicals** – virtual model of manufacturing that allows investigation of factors that influence quality of the output product based on input ingredients and machine settings
IBM Plant Performance Analytics

Turn plant floor equipment data into valuable and actionable insights through advanced analytics.

- **Avoid production losses** - predictive visibility into losses that impact OEE enables plant management to proactively address problems to avoid production losses and associated costs.

- **Optimize maintenance plans** - analyze equipment data and maintenance records to predict machine defects and recommend optimum maintenance plan to minimize production downtime.

- **Accelerate problem resolution** - determine probable root causes of equipment failure and prescribe recommendations to mitigate those risks.
Dashboard provides a forecast of overall equipment availability, availability by shifts, metrics for equipment status, alerts and maintenance, asset hierarchy, and station effectiveness.
Dashboard also displays sorted list of alerts and shows 5 predictions and 2 prescriptions for assets with alerts.
5 predictions and 2 prescriptions for critical assets.

Defective part or parameters that contribute to the problem

Time the asset failure problem is expected to manifest

Expected time required to rectify problem based on historical data

Statistical probability (%) of defect occurring

Statistical probability (%) of downtime occurring

Recommended repair schedule

Recommended resource(s) to remedy the problem
Envision a future where every product has a digital equivalent.