Digitalization from a Metrological Point of View

Symposium on International Trend of Metrology
:: Metrology for Industrial Innovation ::

Centre of Measurement Standards & National Measurement Standards
30th Anniversary Celebration

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Outline

- Digitalization/Industry 4.0 - Introduction
- Metrology for the digitalization (PTB)
  - Time
  - E-Health
  - Legal Metrology
  - Standardization
  - Simulation
- Examples

References
Industrie 4.0 - What does it mean?

From Industrie 1.0 to Industrie 4.0

First Industrial Revolution
through the introduction of mechanical production facilities with the help of water and steam power.
First mechanical loom, 1784

Second Industrial Revolution
through the introduction of a division of labor and mass production with the help of electrical energy.
First assembly line, Cincinnati slaughterhouses, 1870

Third Industrial Revolution
through the use of electronic and IT systems that further automate production.
First programmable logic controller (PLC), Modicon, 1969

Fourth Industrial Revolution
through the use of cyber-physical systems

The first industrial revolution
Steam engines, machinery

Steel production in England

1780: 100,000t
1870: 5,800,000t
The second industrial revolution
Assembly lines, electrification

Assembly time chassis Model T:

<table>
<thead>
<tr>
<th>Year</th>
<th>12:30h</th>
<th>1:33h</th>
</tr>
</thead>
<tbody>
<tr>
<td>1913</td>
<td></td>
<td></td>
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<tr>
<td>1914</td>
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</table>

The third industrial revolution
Electronics, ICT, robots

World-wide sold industry robots

<table>
<thead>
<tr>
<th>1 pc.</th>
<th>160,000 pcs.</th>
</tr>
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<tbody>
<tr>
<td>1961</td>
<td>2012</td>
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</table>
The fourth industrial revolution

2016: Intelligent, flexible and individualized production:

Example: Adidas

Individual running shoe from 3D-printer


Industrial revolutions - Drivers

Source: http://www.mav-online.de/c/document_library/get_file?uuid=1e6c64af-b5dd-4a74-85fe-e0751fb9250c&groupId=32571331
What is Industry 4.0

- Industry 4.0 combines production methods with state-of-the-art information and communication technology
- the driving force behind this development is the rapidly increasing digitization of the economy and society
- the technological foundation is provided by intelligent, digitally networked systems that will make largely self-managing production processes possible
- in the world of Industrie 4.0, people, machines, equipment, logistics systems and products communicate and cooperate with each other


Source: Siemens

smart processes

smart services

smart products

Internet of things and services

01: Digitization and integration of vertical and horizontal value chains
02: Digitization of product and service offerings
03: Innovative digital business models
Metrology for the digitalization

3. Legal Metology
   - Smart Meter
   - Cloud-Metrologie
   - IT-Sicherheit

2. E-Health

1. Time
   → - safe (NTP…)
   → - precise (PTP…)
   → …real time

4. Standardization
   SI-based protocols

5. Simulations
Basistechnologie und Treiber aktueller Technologiefelder der Digitalen Agenda (Industrie 4.0, Internet der Dinge, intelligente Energienetze und Big Data) [1, 2]

Cloud Computing stellt neue Herausforderungen an alle Beteiligten im gesetzlichen Messwesen, z. B. in INDUSTRIE 4.0

Neues MessEG unterstützt den Einsatz dieser Technologie

Neue Marketingkonzepte der Industrie liegen bereit

PTB baut ihre Koordinierungs- und Führungsrolle als international anerkanntes Kompetenzzentrum für Dienstleistungen im gesetzlichen Messwesen für Industrie und Wirtschaft und Marktaufsicht weiter aus.


Metrology for the digitalization

1. Time

- safe (NTP...)
- precise (PTP...)
- ...real time

Legal time in Germany

Ways for the dissemination of the legal time in Germany

time is realized by and traceable to PTB

- long-wave-transmitter DCF77
- internet ptbtime3.ptb.de
- telephone +49 531 512038

disadvantages

- slow (telephone)
- uncertain (DCF77, internet)
Who needs the exact time

- reliable and free time information for society
  Study: Economic benefit of DCF77 is 14 x higher than effort

- accurate, reliable, cost-effective time for Industrial use

- accurate, trustworthy, traceable time for the markets
  Stock market (high-speed trading)
  Trade of goods

- accurate time and frequency for research
  New opportunities through better clocks / time distribution

Time and frequency distribution

opt. frequences

time transmission

planned extensions

Physikalisch-Technische Bundesanstalt  Braunschweig und Berlin  Nationalis Metrolgieinstitut
Metrology for the digitalization

2. E-Health

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E-Health - Medicine 4.0

• high backlog in digital healthcare
• interested patients are development drivers
• innovation potential for health care and economy
E-Health - Medicine 4.0

- modern diagnostics rely on the variety of multiparametric data such as.
  - in vitro diagnostics DNA, vital parameters (blood pressure, ECG, breathing temperature)
  - multi modal images,
  - patient records
- systematic analysis by means of electronically supported health management (E-Health)
- potential is used to little:
  - lack of networks,
  - lack of interoperability,
  - lack of security,
  - lack of comparability and standardization

E-Health - Challenges

Electronic health management:
- target: classification of patients in order to provide appropriate therapies
- use of statistical methods („big data“) for the classification of patients
- metrological standardization provides the basis of a better combination of data (pooling)
Metrology for the digitalization

3. Legal Metrology
- Smart Meter
- Cloud-Metrologie
- IT-Sicherheit

Legal metrology

- Protection for customers and users
- Confidence in the correctness of measurements
**Legal metrology**

**From design to product**

- **manufacturer**
  - product design
  - production
- **market launch**
- **user customer**
- **conformity assessment**
  - Scientific and technical consulting
- **market surveillance**

**Industrie 4.0 and Legal Metrology**

**Criticism**: Regulation is an "inhibitor for innovation"!

1. regulations increase „time-to-market“
2. costs for IT security are too high!
3. „technology gap“ (NBs, MSAs)
4. no harmonization in Europe!

**PTB aims to provide the following:**

- **Reference architectures** for new technologies (1, 2, 3, 4)
- **Simple verification methods** for MSAs (3, 4)
- **Risk analysis and assessment** to achieve „adequate“ IT security (2, 3)
- **Coordination of services** in Europe via WELMEC (4)
- **Planning / handling security** for manufacturers
Industrie 4.0 and Legal Metrology

Virtual Measuring Instrument:
- Data stored in the cloud
- Measuring software in the cloud (SaaS)
- Access to the instrument / on parts via cloud

Vision: The “Metrology Cloud”…
... enables coordinated services in Europe using Industrie 4.0 technologies

- Remote diagnostics
- Remote maintenance
- Predictive maintenance
- Remote calibration
- Remote re-certification
Balance

weighing module: sensor

terminal: display, control

cable link

Balance

in conformance to legal regulations

manufacturer

interface
Metrology for the digitalization

4. Standardization
SI-based protocols

Communication

communications are essential
they allow to evaluate processes
all digital evaluations rely on numbers and rules
(how far, how fast, how expensive, ...)

transmitter
receiver
Communication

Numbers have to be

*unambiguous*,
*efficient*,
*easy to understand*,
...

exchangeable

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Underestimated risk - diversity

- problem: There is no unity and clarity in the digital communication
  the diversity of data seems to be increasing!

  units: meter, feet, sea-, land-, air-miles, …
  characters: Ä, Ö, Ü, …
  number systems: decimal, hexadecimal, binary, …
  …

- economic disaster due to diversity and redundancies
  \[ z = \frac{n(n-1)}{2} \]
Kosten und fehlende Sicherheit

- Mars Climate Orbiter¹ 1999
  mix up of metric and imperial units
  destroyed at landing approach (125 Mio US$)

- 2005 NASA-“Constellation-Program“
  [landing on the moon] rejected!
  harmonisation of units would cost
  370 Millionen US$².

- 1983 Air Canada Flug 143 „Gimli-Glider“:
  refuelling in pound/litre instead of kg/litre

¹NASA; Mars Climate Orbiter Mishap Investigation Board Phase I Report.
Common data exchange format

\[ Y = y \pm U(k) \] [SI] UTC

- **mandatory**
- **universal coordinated time**
- **units (Système Internationale d’unités)**
- **coverage factor**
- **expanded measurement uncertainty**
- **measurement value**
- **measurement result**

**Example**

\[ m = 5 \pm U(k=2) \text{ kg} \]

2017-05-03T05:10:00
Digital Calibration Certificate

Digital calibration certificate
Digital calibration certificate

Three parts

• unique information (strict regulated, XML format)
  e. g. manufacturer, date, identification, ….

• measurement results (partly regulated)
  regulated: SI-units; data format
  unregulated: (language, additional information, graphics)

• measurement-data (unregulated)

Validation of Metrological Algorithms
Validation of algorithm in the past

Individual NMIs offer validation
- almost without report
- PTB offers report for Gaussian test for prismatic objects

Manual operation via email -> cost intensive and time consuming

No agreement among NMIs
Validation of algorithm today

Service provider

Service user

NMI

Internet

industry

calibration laboratory

metrology-institutes

TraCIM - evaluation process
Test Bed
Competence Centre for Windenergy

Competence Centre - Windenergy

Building Euler I: March 2016 – December 2017
Building Euler II: June 2017 – December 2018
In operation: December 2020

Funding BMWi/PTJ: 9.5 Mio. €
PTB-Budget (building, infrastructure): 5.5 Mio. €
Total: 15.0 Mio. €
Competence Centre - Windenergy

3D in m coordinate metrology

3Dv in m/s 3D wind-vector measurement

F \cdot l in N \cdot m torque measurement

Torque standard measuring device

fundament 1.6 Mio. €
machine: 5.3 Mio. €

17 m x 9 m x 5.4 m (3.6 m)
Torque standard measuring device

Transducer - digital twin

- temperature (-gradient)
- communication via WiFi
- creep
- measurement
- humidity
- amplifier
- material properties
- strain gauges
- EMC
Metrological Cyber Physical System

M-CPS

encoding

authentication

digital twin

measurement result

$Y \pm U [SI]$ ...

embedded system

interface

Metrology for the Digitalization of Economy and Society
PTB Study

Metrology for the Digitalization of Economy and Society

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