

Photogrammetry for Industry 4.0 – Prospects and Challenges



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Riva del Garda

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Photogrammetry for Industry 4.0 – Prospects and Challenges

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Outline

- Introduction
- What is Industry 4.0?
- Photogrammetric solutions
- Accuracy and verification
- Summary and outlook

Introduction

Historical development

Industrial photogrammetry



Large-format camera
GSI CRC-1 (1986)



Digital image comparator
GSI AutoSet-1 (1986)

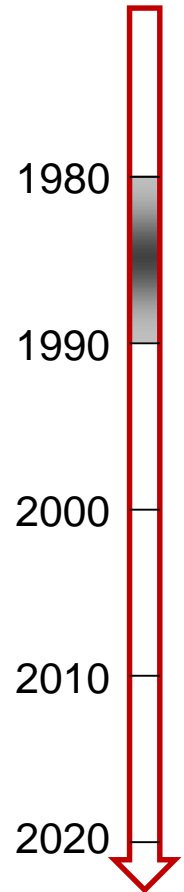
image format: 230 x 230 mm²
accuracy: 1µm



Large-format camera
Rollei LFC (1990)



Digital image comparator
Rollei RS-1 (1988)



Introduction

Historical development

Industrial photogrammetry



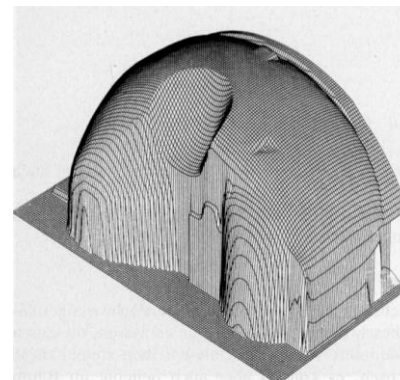
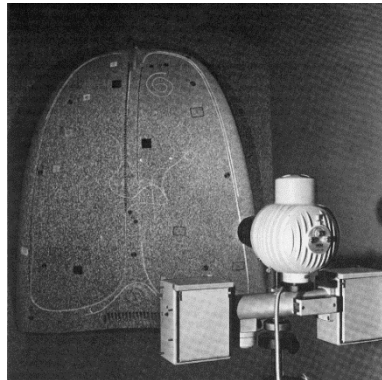
Online videogrammetry
Mapvision (1987)



CCD video cameras



Indusurf
Zeiss (1988)



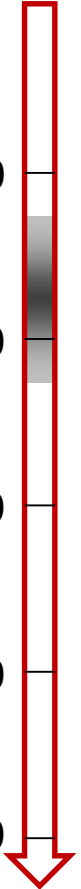
1980

1990

2000

2010

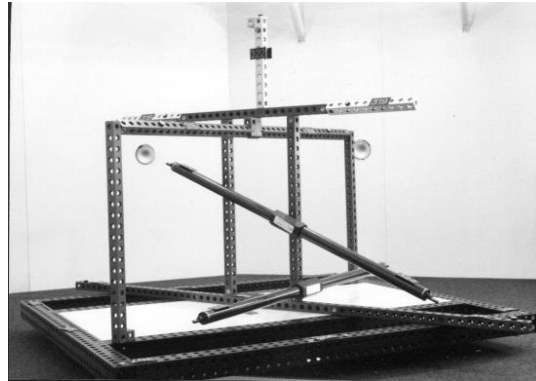
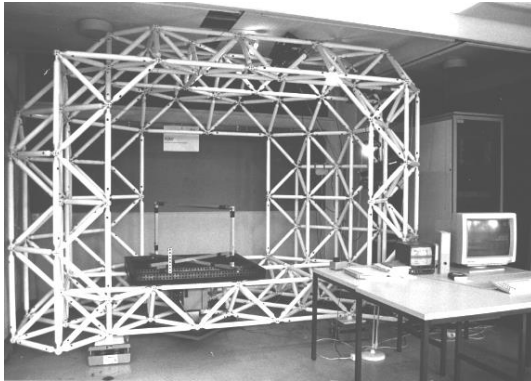
2020



Introduction

Historical development

Industrial photogrammetry



1980

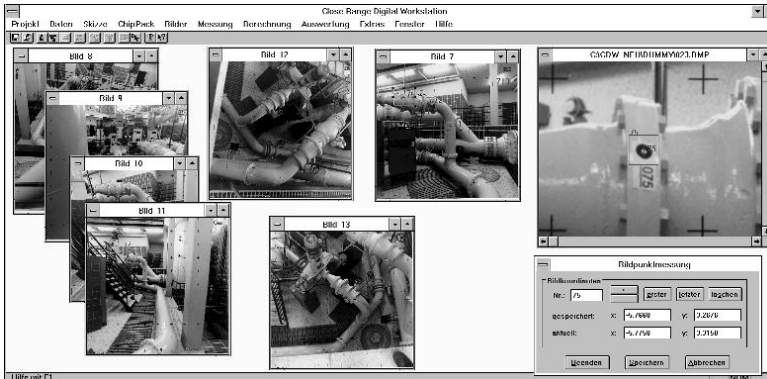
1990

2000

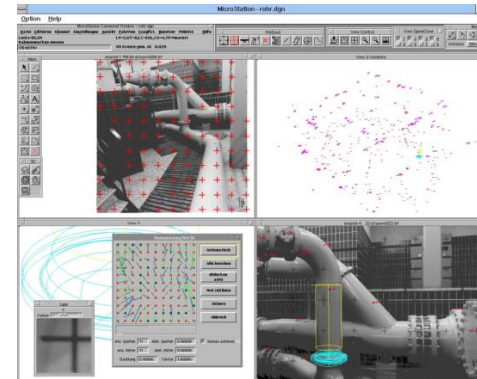
2010

2020

Programmable Optical Measurement System (POM)
Leica/Rollei (1991)



Interactive multi-image processing CDW
Rollei (1991)



Interactive multi-image CAD system PHIDIAS
Phocad (1991)

Introduction

Historical development

Industrial photogrammetry



Still-video camera
Kodak DCS 460 (1996)



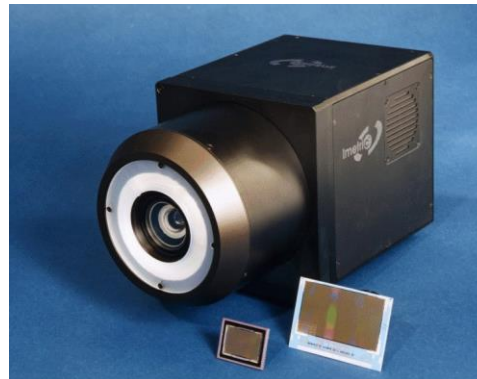
Tactile stereo system
VSTARS (2000)



Tactile mono system
Metronor (2002)



Fringe projection system
GOM (2000)



Large-format camera
Imetric (2000)



Multi-camera measurement system
AICON (2006)

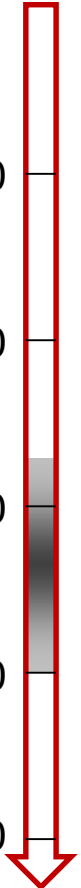
1980

1990

2000

2010

2020



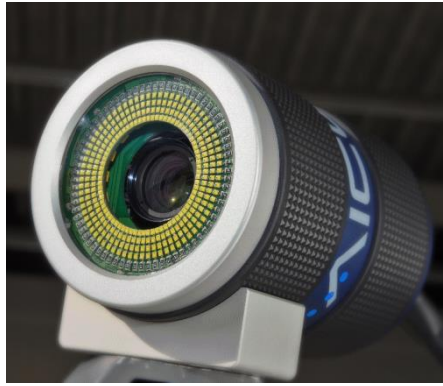
Introduction

Components

Cameras



High quality DSLR cameras



High quality (metric) cameras



High-speed cameras

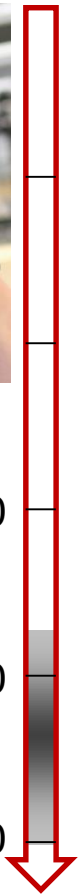


Metric stereo camera

2000

2010

2020



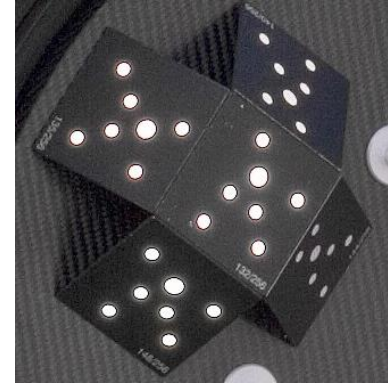
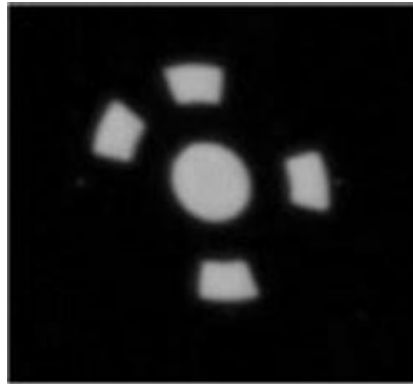
Introduction

Components

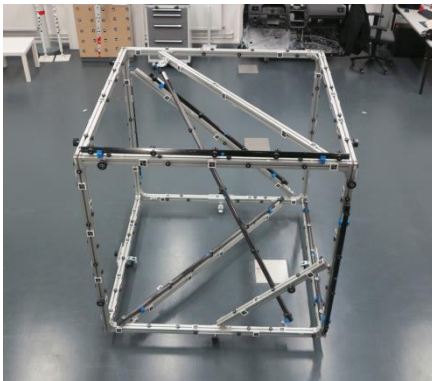
Scale bars and targets



Retro-reflective targets



Coded targets



Calibrated and certified scale bars

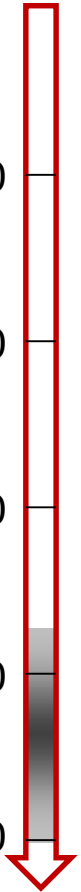
1980

1990

2000

2010

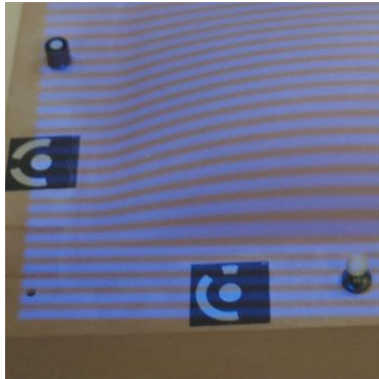
2020



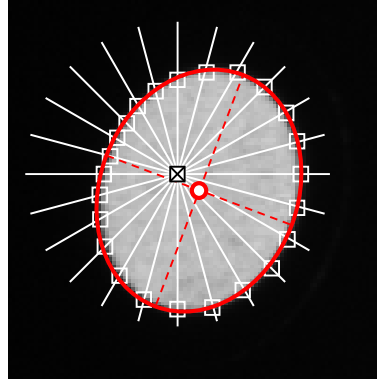
Introduction

Components

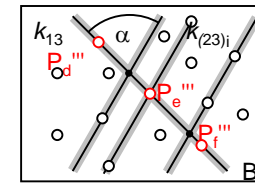
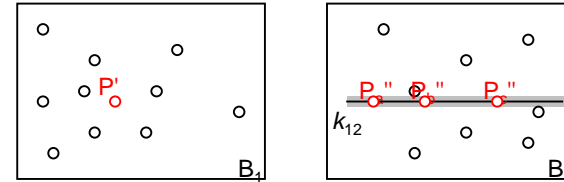
Software



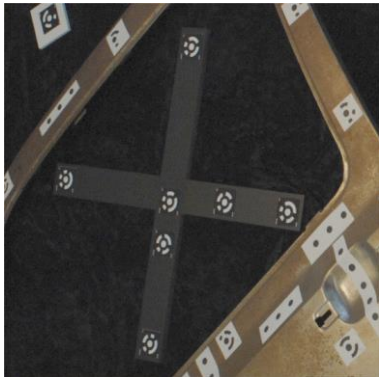
Feature extraction



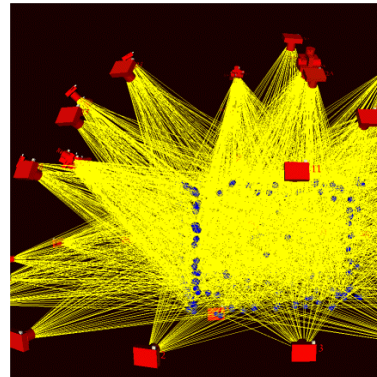
Subpixel measurement



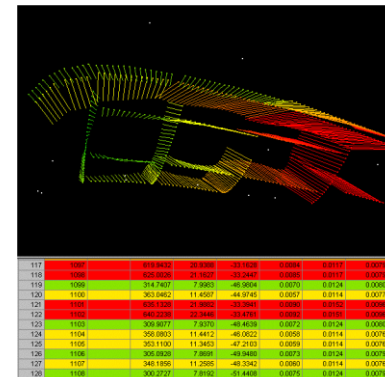
Matching



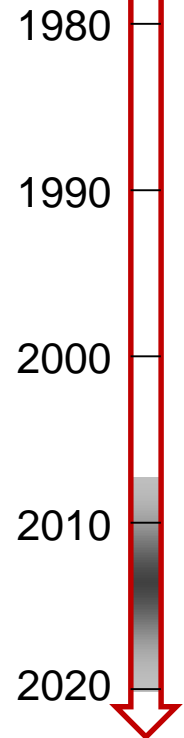
Approximate values



Bundle adjustment
Spatial intersection



Post-processing
Interfaces



Introduction

Markets

Industrial sectors (selection)



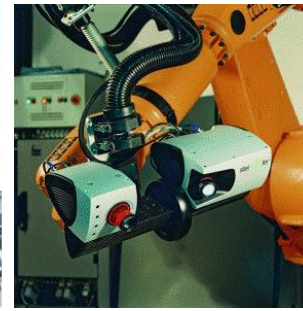
Automotive



Aerospace



Ship building

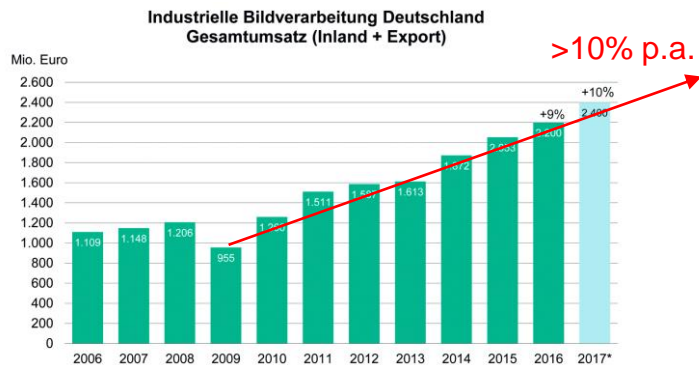


Robotics



Medicine

Annual growths



Industrial image processing Germany, 2005 - 2016

Global players (examples)



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JADE HOCHSCHULE
Wilhelmshaven Oldenburg Eilsfleth

What is Industry 4.0?

Definitions

Definition

Networking of all components in self-organized production:

- Human beings
- Machines and tools
- Production facilities
- Logistics
- Products



by means of digital information and communication technologies for all stages of the life cycle of a product.

Industry 4.0 = 4th industrial revolution

1. revolution: water and steam power
2. revolution: mass production with conveyor belts
3. revolution: electronics and IT (e.g. integrated circuits)
4. revolution: software, internet of things, big data ...

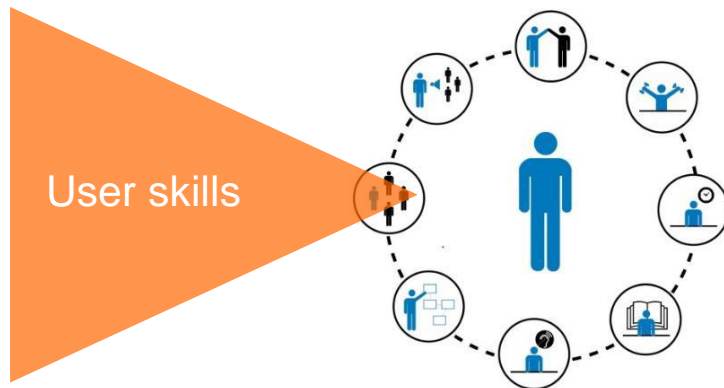
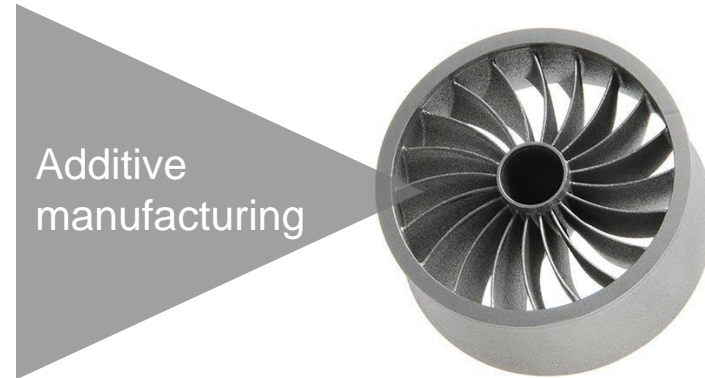
} defined afterwards

} defined before

What is Industry 4.0?

Definitions

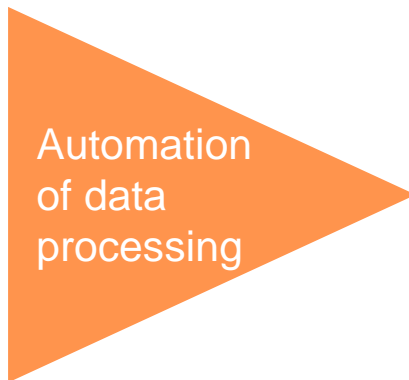
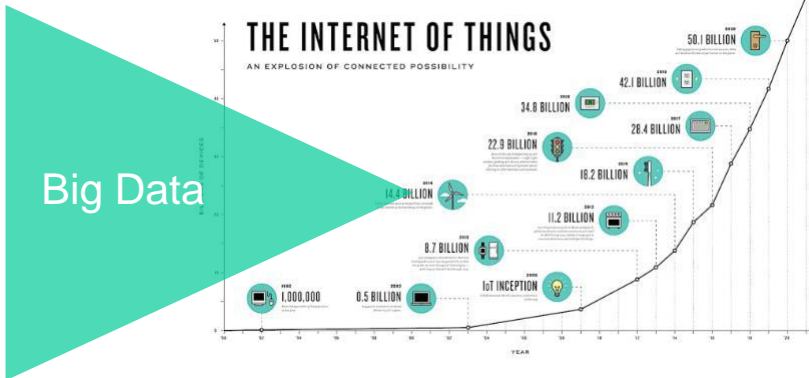
New tools (selection)



What is Industry 4.0?

Definitions

Information processing

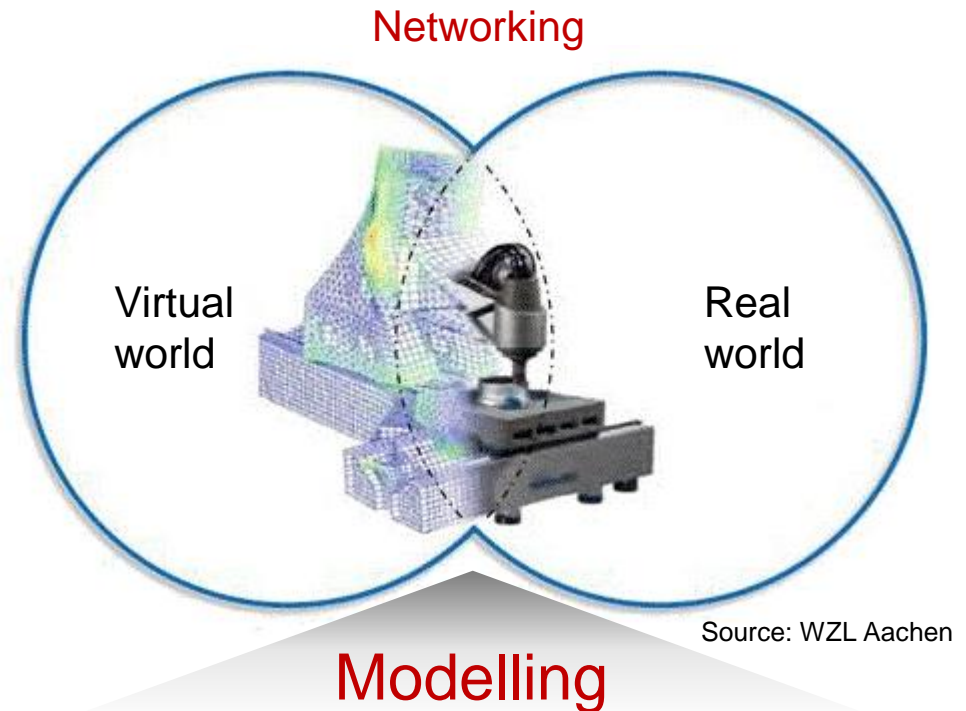


What is Industry 4.0?

Metrology

The impact of Industry 4.0 on industrial metrology

- Individualisation of products
- Flexible manufacturing
- Combining virtual and real worlds
- Interfacing to production



Metrology is the key factor for interfacing real and virtual world

What is Industry 4.0?

Metrology

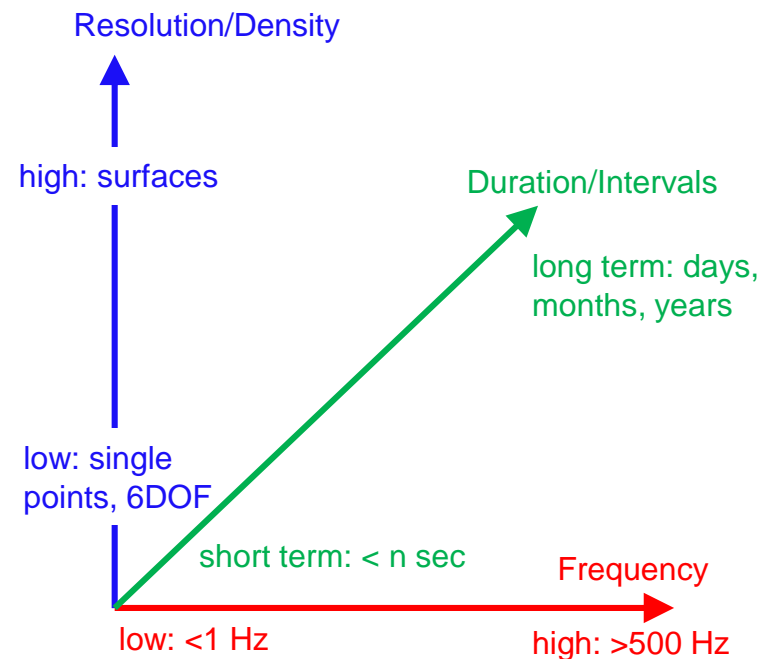
The impact of Industry 4.0 on industrial metrology

The role of metrology changes:

- Final inspection becomes less important
- Feedback loop to production
- In-, at- and near-line installations growing fast
- MAA (Measurement Assisted Assembly)

Here photogrammetry offers:

- Scalable and flexible solutions
- Fast and precise multi-point measurements
- Contactless (ambient) measurements
- Image archives (true view)
- Dynamic and real-time output



Source: AICON

Photogrammetric solutions

Metrology

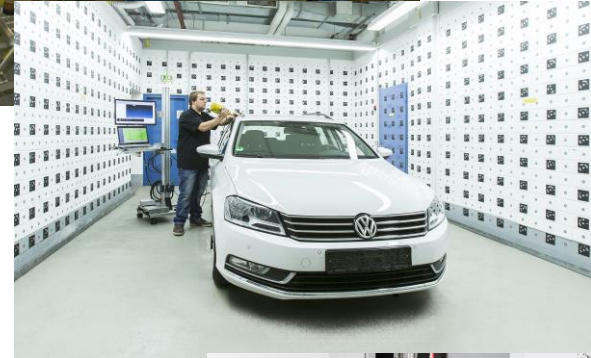
Photogrammetric tasks

Offline:

- 3D point measurements
- 3D profiles and surfaces
- shape and size, quality control
- deformations, vibrations



Source: GSI



Source: AICON

Online:

- robot calibration and control
- machine control
- inline measurements (100% inspection)
- control of autonomous systems
- ...



Source: GOM

Photogrammetric solutions

Metrology

Point-probing solutions



Offline photogrammetry



Online imaging with FOV projection



High speed 6DOF measurement



Measurement cabin



Multi-camera probing by intersection



Single-camera probing by resection

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Photogrammetric solutions

Metrology

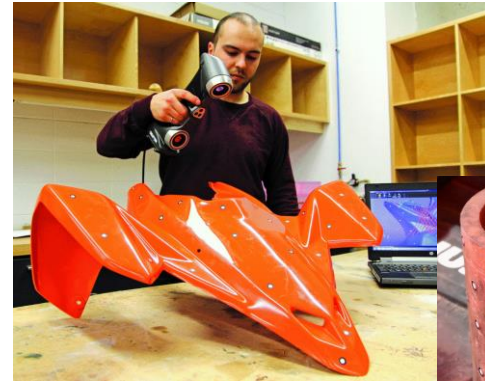
Surface-probing solutions



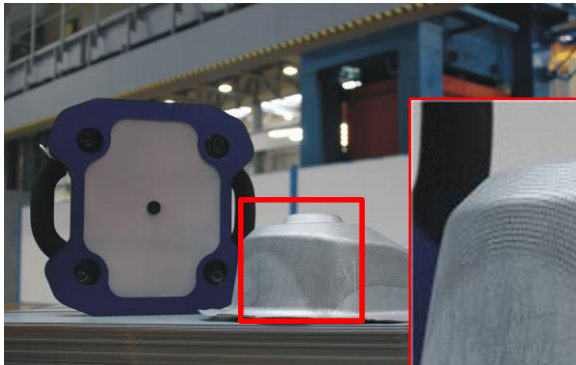
Fringe projection



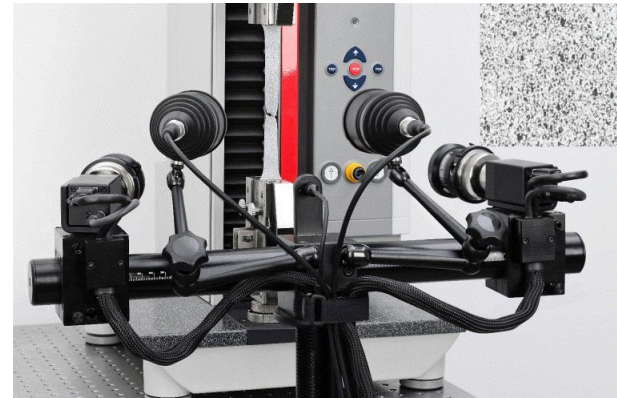
GOM ATOS
Compact Scan



Laser projection
Creaform HandyScan



Vialux
AutoGrid



Digital Image Correlation (DIC)
GOM ARAMIS



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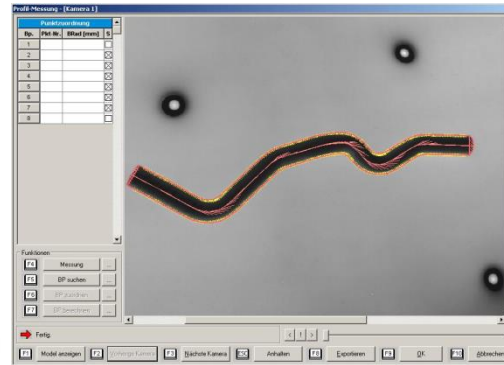
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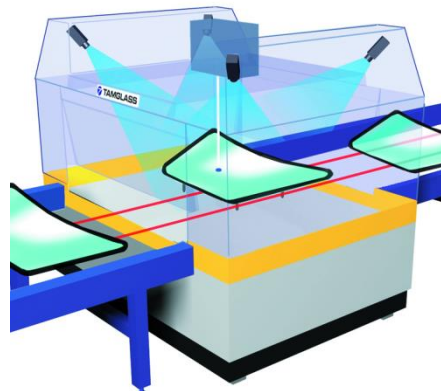
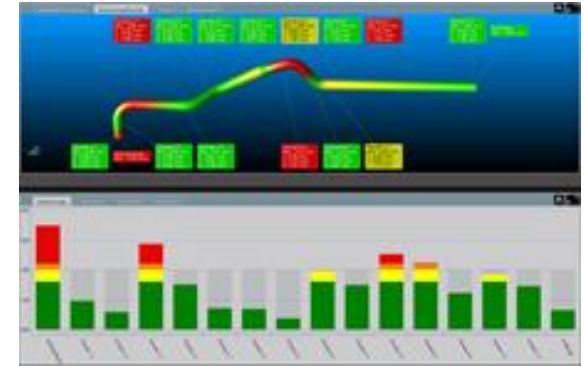
Photogrammetric solutions

Metrology

Integrated measurement systems



Source: AICON



Source: Mapvision

Photogrammetric solutions

Metrology

Integrated measurement systems



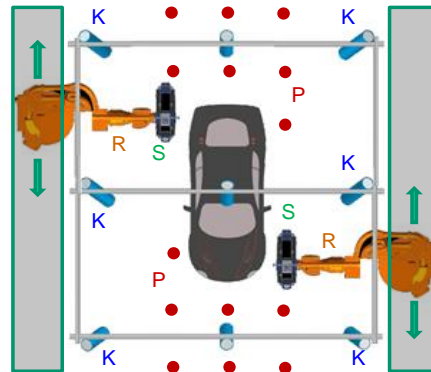
K: cameras

S: sensors with locator L

R: robot

P: reference points

Source: AICON



Source: GOM



Source: Zeiss

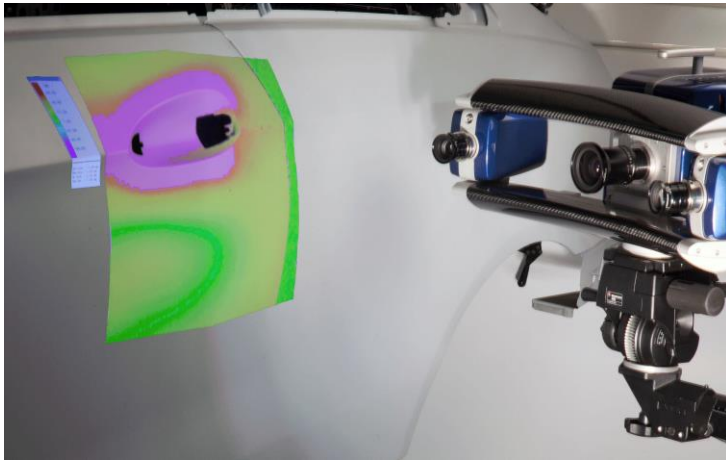
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Photogrammetric solutions

Metrology

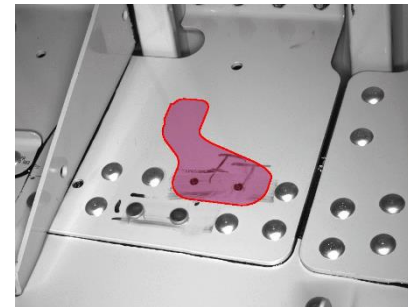
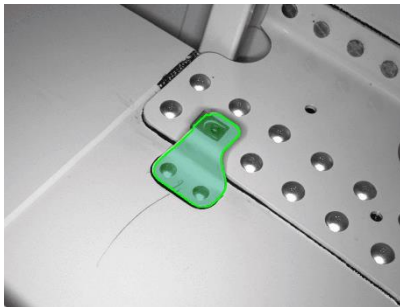
3D projection and surface control



Projection of surface deformations (AICON)



Projection of object features (Fh IGP)

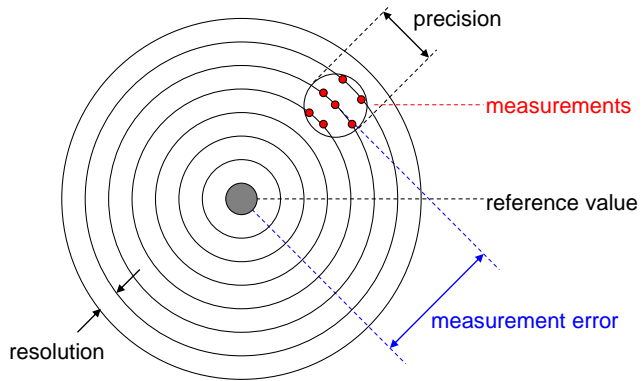


Check for completeness in aircraft industry (Premium AEROTEC)
left: mounting ok; middle: erroneous position; right: missing part

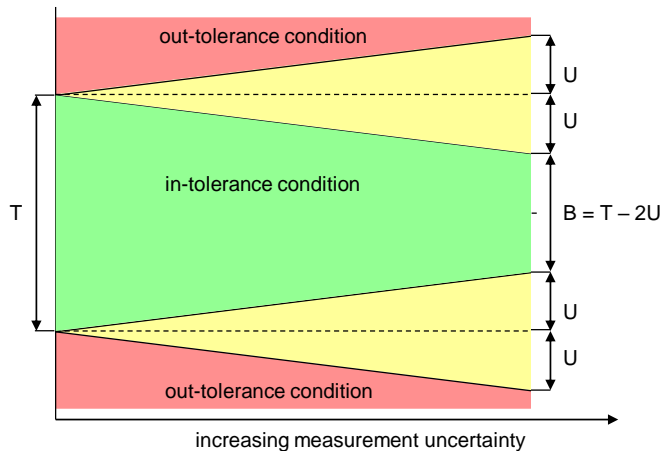
Measurement uncertainty and verification

Terminology

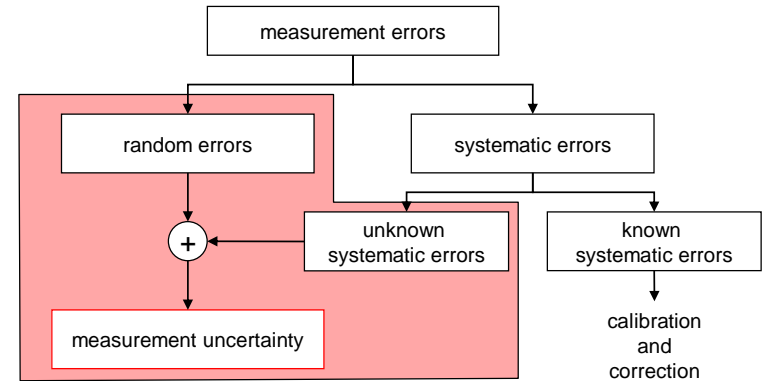
Resolution, precision and accuracy



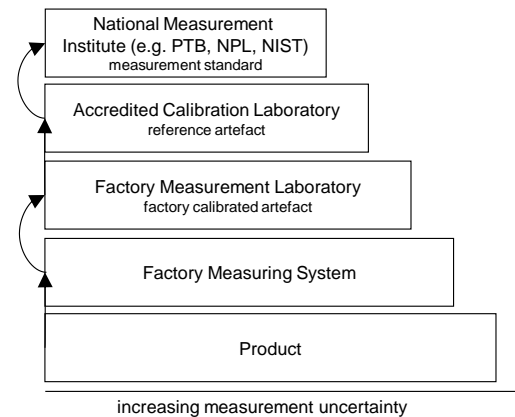
after Hennes, 2007



Suitability of testing device or procedure for in-tolerance evaluation



Measurement error and measurement uncertainty

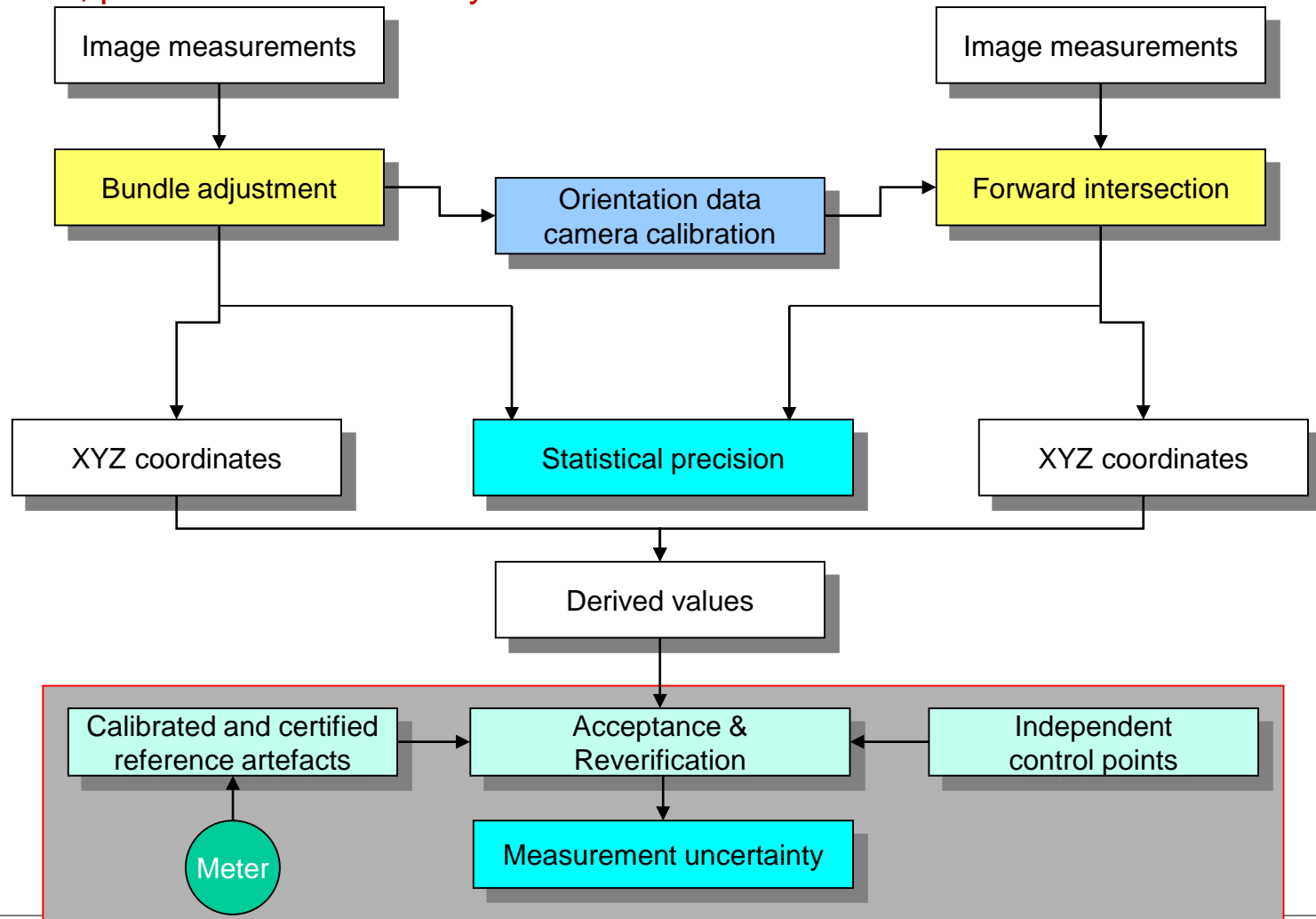


Traceability to national standards

Measurement uncertainty and verification

Workflow

Resolution, precision and accuracy



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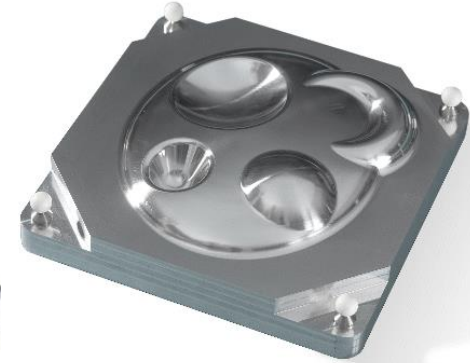
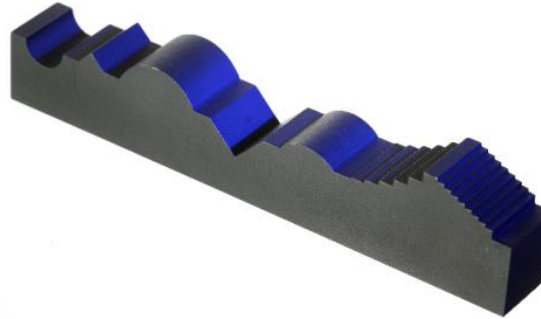
Measurement uncertainty and verification

References

Reference bodies and test artefacts

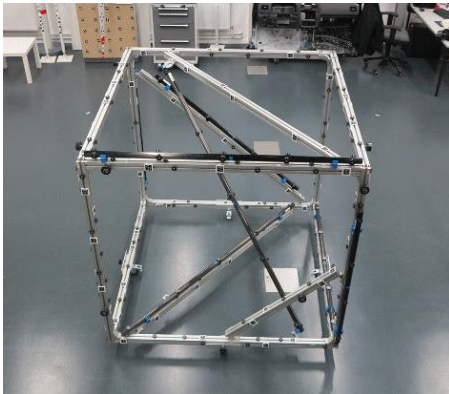


Ball plate



Source: NPL

Free-form artefacts



Arrangement of
reference scale bars (VDI 2634)



Dumb-bell artefact

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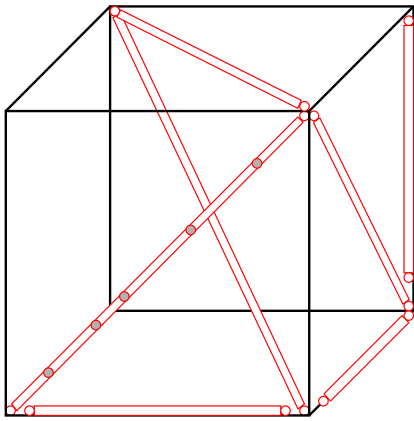
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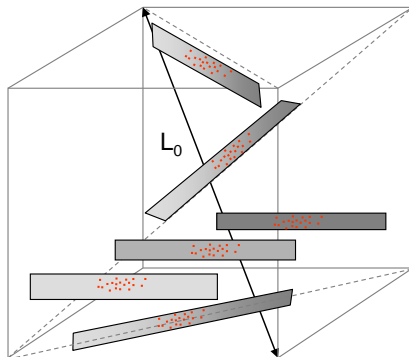
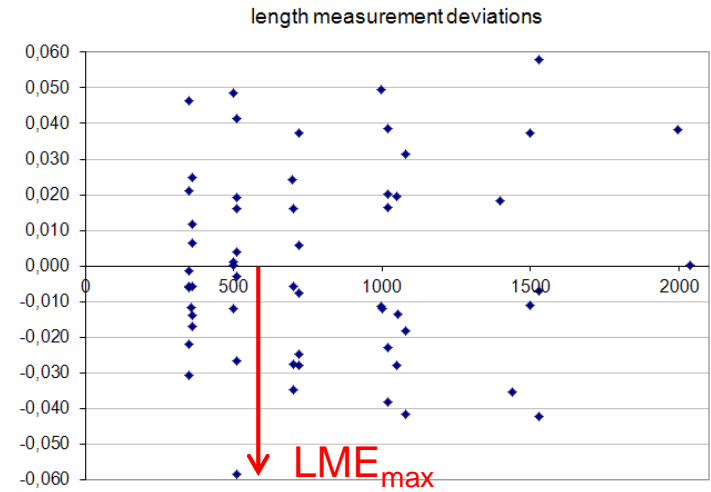
Measurement uncertainty and verification

References

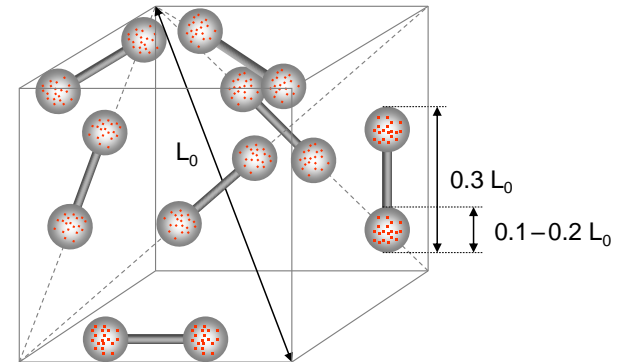
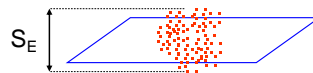
VDI/VDE 2634



Assessment of length measurement error (LME)



Assessment of plane probing error



Assessment of sphere distance error

Summary and outlook

Challenges

- **Flexibility**
→ object properties (shape, size, material)
- **Accuracy**
→ scalable, verified, certified, accepted
- **Speed**
→ process frequency
- **Reliability**
→ environmental conditions, repeatability, 24/7 operation
- **Robustness**
→ error detection, 'intelligent' reactions on unforeseen events
- **Documentation**
→ reporting, archiving, assignment to individual object
- **Analysis**
→ comparison with nominal values (e.g. CAD), quality analysis, trend analysis
- **Interfacing**
→ robots production tools databases

Summary and outlook

Prospects of Industry 4.0

- Higher flexibility in production
- Improved quality of production
- Decreased manufacturing costs
- Decreased maintenance effort

Prospects for optical metrology

- Growing markets for metrology
- Images as data source and archives
- Intelligent systems (machine learning)
- Specialised vs. universal systems
- Education
- Research topics:
 - learning systems
 - real-time surface measurement
 - semantic modelling
 - simulation
 - from CAD to measurement to analysis to production control
- Conferences and shows in optical metrology: ISPRS, 3DMC, CMSC, EPMC, O3D, Fraunhofer, Control, ...

Thank you for your attention

This presentation was kindly supported by

- Dr. Werner Bösemann (CEO AICON 3D Systems, part of Hexagon)
- Prof. Manfred Schmitt, WZL, Aachen

https://www.youtube.com/watch?v=GfDKkeq_eZU