1ST 3D METROLOGY CONFERENCE
3DMC 2016

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Research Alliance

New advances in metrology of large parts

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- ADVANCED PHOTOGRAMMETRY TECHNIQUES
- COMPENSATION OF THERMOMECHANICAL EFFECTS
- CURRENT / FUTURE RESEARCH

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- **INTRODUCTION**
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LARGE PART METROLOGY: CURRENT SCENARIO

- Large metal parts with geometrical and free-form surfaces.
- High value parts; tight manufacturing tolerances.
- Verification critical to ensure excess material for machining.
- Volumetric comparison with nominal dimensions and Geometric Dimensions & Tolerance (GD&T) analysis.

LARGE PART METROLOGY: LIMITATIONS

- Fast measuring techniques required.
- Low measurement uncertainties required.
- Thermal effects affect measurements.
- Mechanical effects (own weights) affect measurements.

Research activities:

- Automatic feature extraction
- Dense photogrammetry
- Compensation of thermo-mechanical effects

EVOLUTION OF PORTABLE MEASURING DEVICES FOR LARGE PART VERIFICATION:

Geometrical inspection based on discrete point cloud

-Laser tracker

-Target Photogrammetry

Certified many years ago

Volumetric surface and geometrical inspection based on dense point cloud

-Hand held scanner

-3D scanner

-Structured light

Recently certified

-Dense Photogrammetry

Not certified

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AUTOMATIC FEATURE EXTRACTION

- Optical feature probing: estimation of drill center positions.

Two techniques involved:

- Photogrammetry
- 2D Image processing

Challenges:

- Variable room light → Requires the use of spotlights and continuous adjustment of exposure time.
- Light saturation on edges → Causes loss of information.
- Different viewing angles → Requires the combination of camera variable focus.

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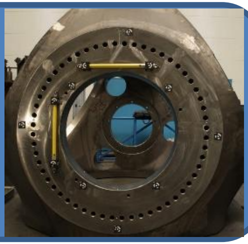
METHODOLOGY

1

PHOTOGRAMETRIC NETWORK DESIGN & SIMULATION

Hardware & software definition, measuring procedure, theoretical uncertainties

PHOTOGRAMMETRY MEASUREMENT



Images & bundle result (E.O & I. O)

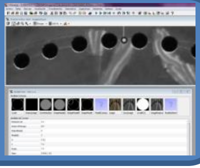
2

THEORETICAL DATA PREPARATION

Hole centers' coordinates definition regarding to a specific coordinate system

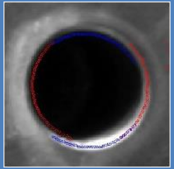
3

IMAGE PROCESSING



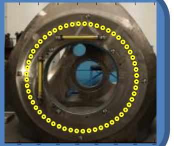
Filtering & ROI establishment

HOLE CENTER 2D POSITION CALCULATION



Ellipse fitting & 2D center estimation

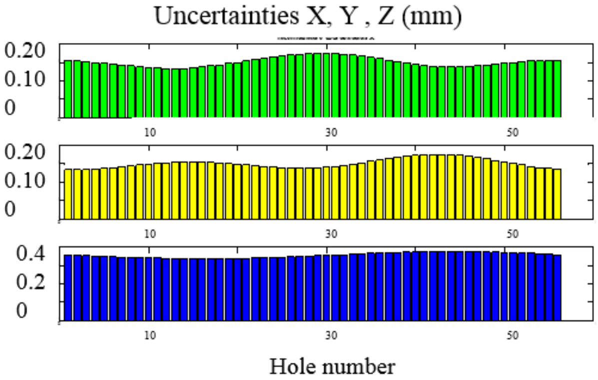
3D COORDINATE OF HOLE CENTERS



Coordinate system transformations to obtain 3D positions

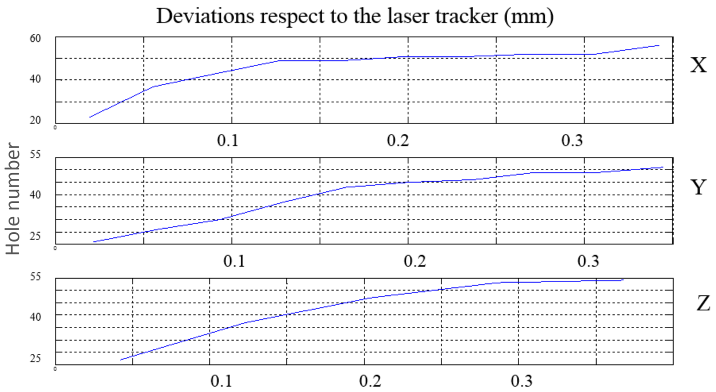
HALCON/MATLAB Libraries

RESULTS FOR PHOTOGRAMMETRY FOR AUTOMATIC FEATURE EXTRACTION



Bundle residuals calculation

U $_{95\%}$ < 0.3 mm (k=2) in XY



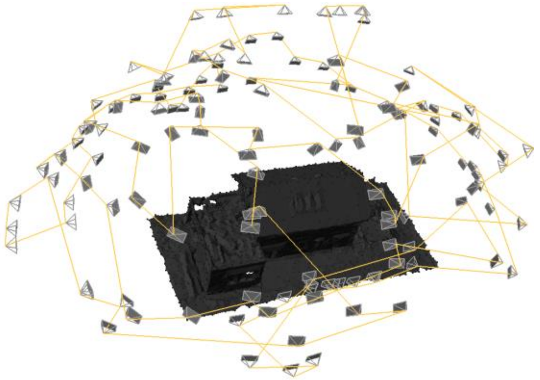
→ Also a measurement of the features with a laser tracker was made and the results compared.

Deviation respect laser tracker

D $_{95\%}$ < 0.3 mm (k=2) in XY

DENSE PHOTOGRAMMETRY MEASURING TECHNOLOGY

- Dense photogrammetry: combination of Multi-View Photogrammetry & Dense Image Matching.
- Surface oriented photogrammetry.
- Camera calibration applied (intrinsic/extrinsic).
- Comercial software available.
- Using targets provides more accurate results.
- Surface texture is critical for the matching process.



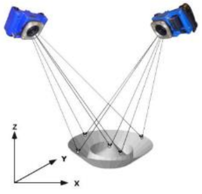
METHODOLOGY:

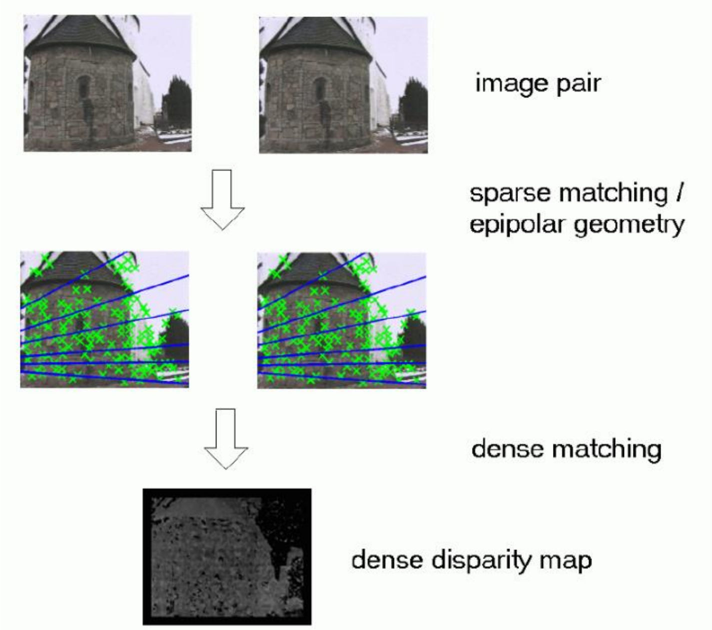
Bundle Adjustment:

- Intrinsic calibration: camera optical model.
- Extrinsic calibration: position and orientation of the images.

Dense matching:

- Relative orientation between images is known.
- Search for corresponding pixels among images.
- Matching is carried out in 2 steps:
  - Sparse matching (few key points)
  - Dense matching (3D cloud of points)





ASPECTS TO TAKE CARE ABOUT:

- Camera and lense adjustments:

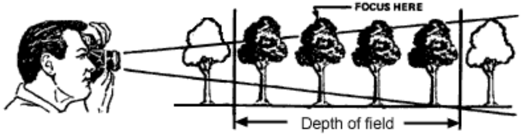
  Depth of field, field of view, exposition time, aperture, contrast, ...

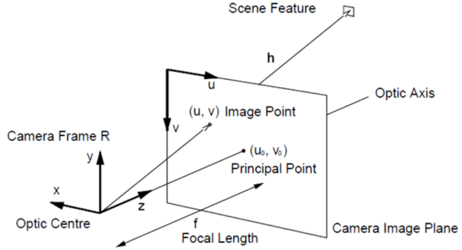
- Image network design:

  Measuring plan, target distribution, image overlapping, scale artifacts, ...

- Self-calibration (non-metric cameras)

  Focal length, optical aberrations,...

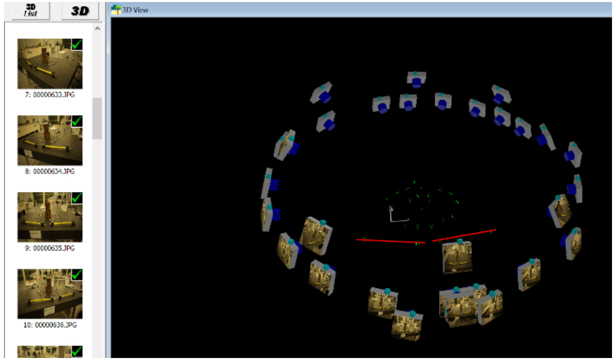




TEST 1: SMALL/MEDIUM SIZE PART

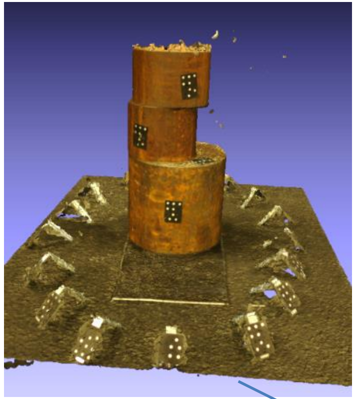
Methodology:

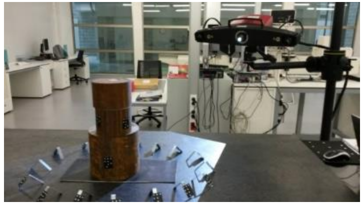
1. Placement of the part with targets and scales.
2. Adjustment of the camera and lense.
3. Image acquisition.
4. Data processing:
   - -Photogrammetry
   - -Dense matching
5. Dense point cloud filtering
6. Polygonization of the dense point cloud (mesh)

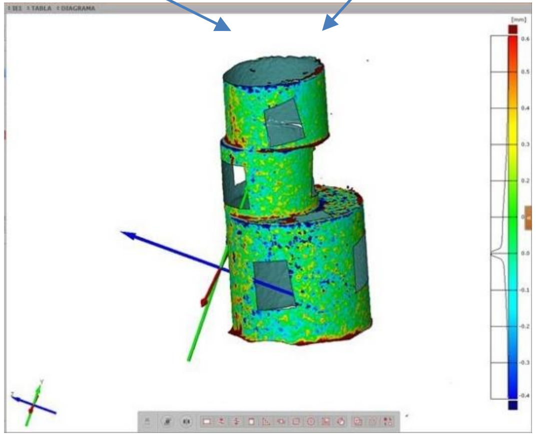


TEST 1: SMALL/MEDIUM SIZE PART RESULTS

- Target photogrammetry accuracy ≈ 0.025mm (RMS)
- High consistency of camera calibration
- High spatial resolution and number of points (10,5 million)
- Part scanned also by 3D scan (Atos)
- Comparison in GOMInspect software by best-fit to estimate the differences.
- Most deviations for surface points <±0.2 mm (2σ)
- Biggest deviations on the edges (critical triangulation)





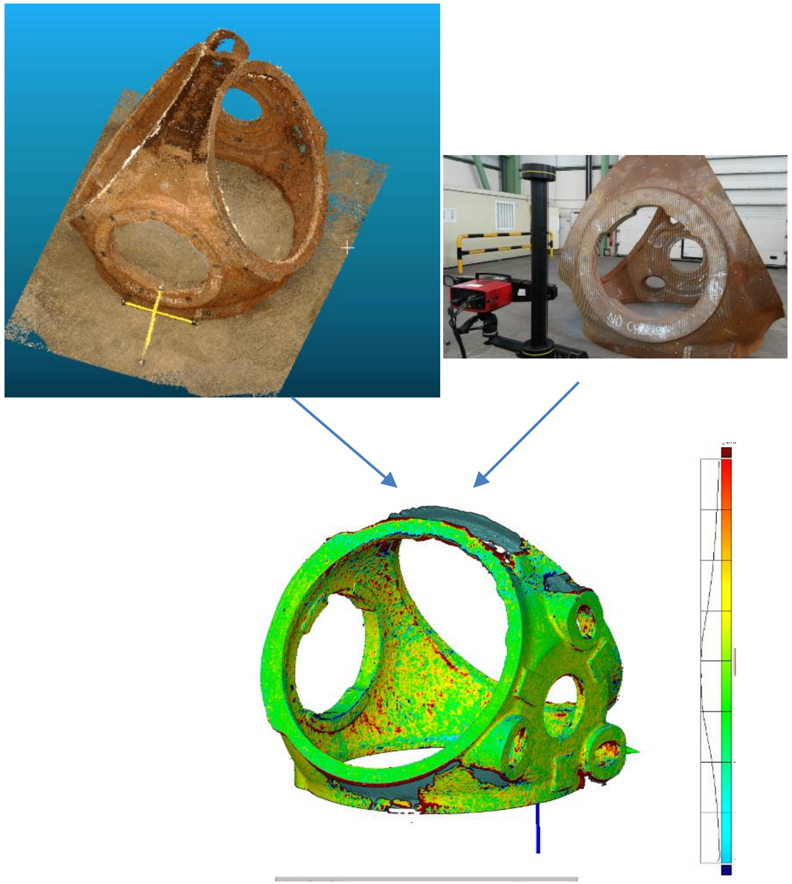


TEST 2: LARGE CAST PART

- Manufacturing tolerance of cast part: 10mm
- Rough texture suitable for dense photogrammetry
- Workshop measuring conditions:
    - Variable lighting
    - Temperature ≠ 20ºC
    - Own weight

TEST 2: LARGE CAST PART

- High consistency of camera calibration.
- Number of points: 2 million
- Spatial resolution ≈ 0.2 mm between points
- Part scanned also by 3D scan (Atos).
- Comparison in GOMInspect software by best-fit to estimate differences.
- Most deviations for surface points <±3 mm (2σ)
- Biggest deviations are located on the edges.



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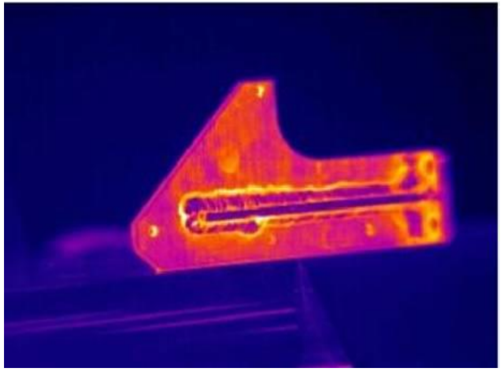
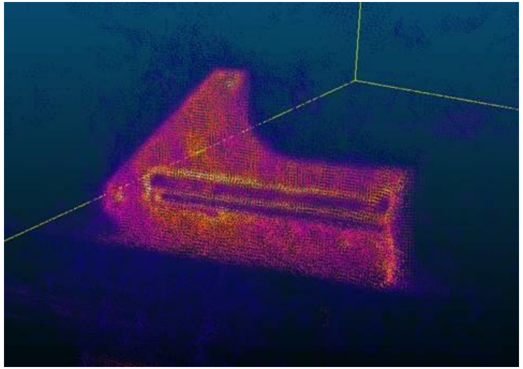
INFRARED DENSE PHOTOGRAMMETRY FOR PART 3D THERMAL MAPPING

Scenario setup



2D thermal images acquisition



3D point cloud generation

PROS OF DENSE PHOTOGRAMMETRY	*CONS OF DENSE PHOTOGRAMMETRY*
• Low cost technology (DSLR + Software) • Versatile (scalable, resolution, accuracy) • Ergonomic • Very fast • Suitable for automatic inspection • Continuous technical advances of cameras and image processing software	• Requires rough, non-homogeneous texture • Measurement uncertainty higher than 3D scan • Measuring noise and outliers • Offline data processing • Rough point cloud data refinement for 3D inspection • User photogrammetric know-how

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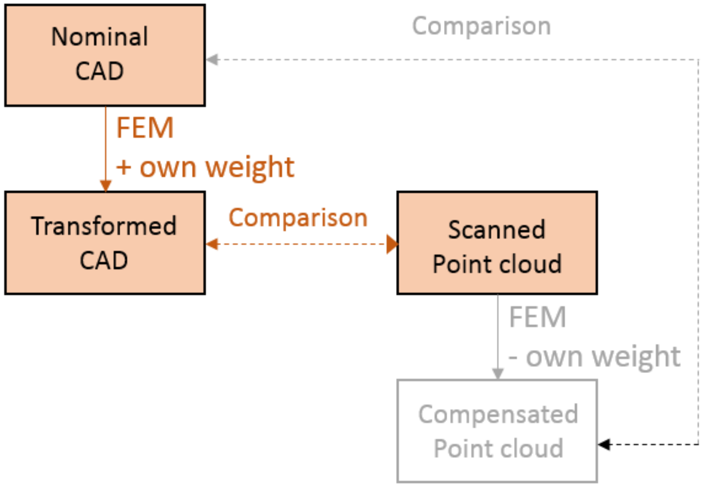
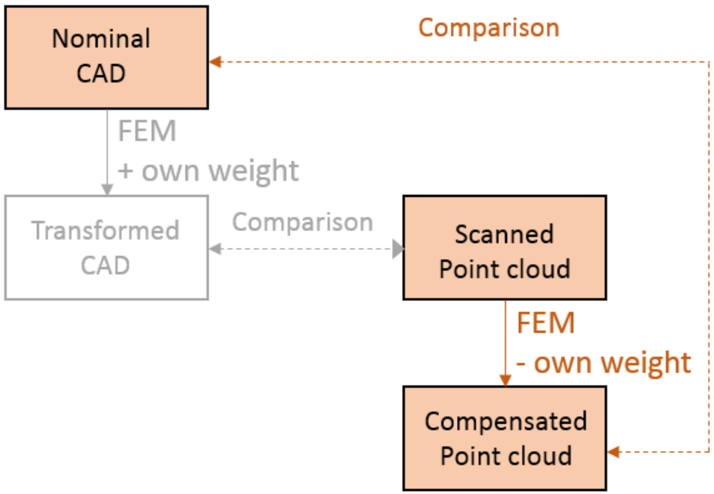
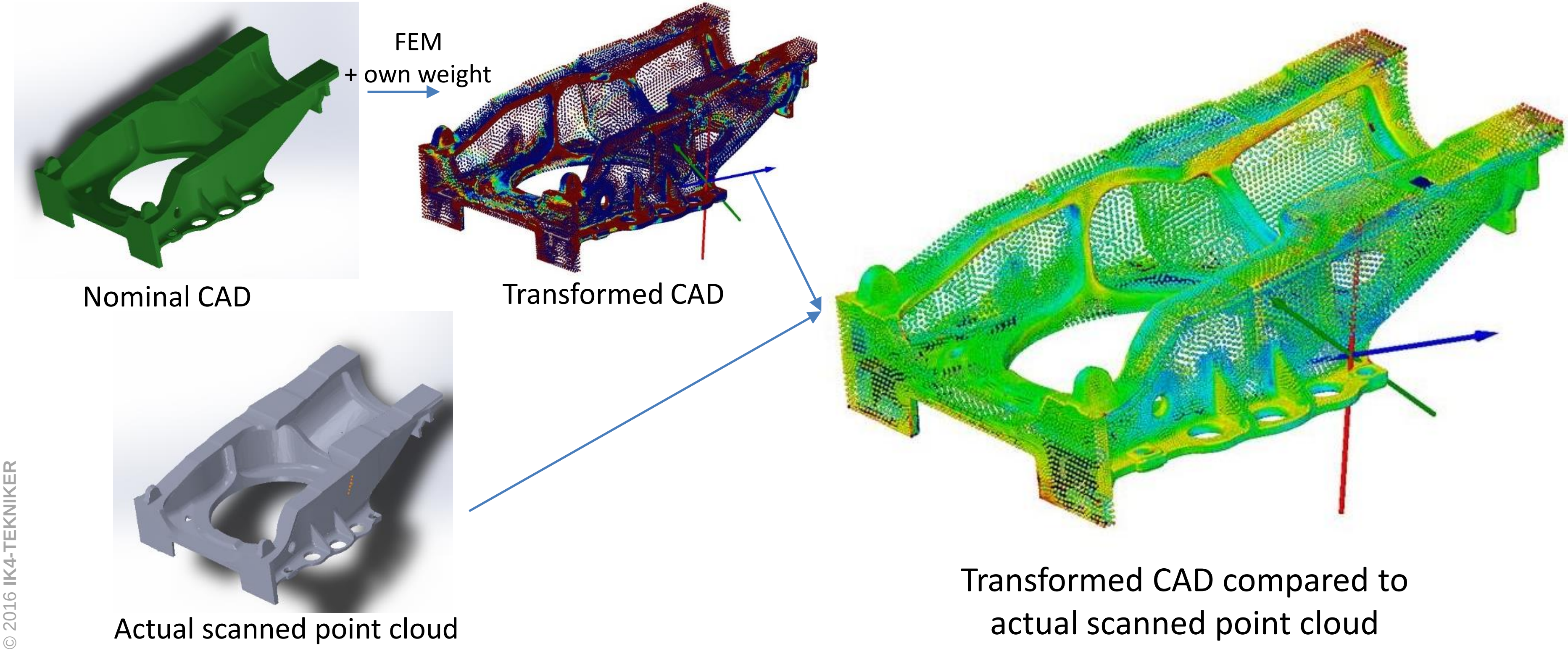
***Method 1*: Transformed CAD vs actual scanned point cloud**



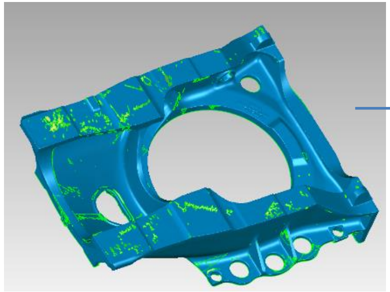
***Method 2*: Compensated scanned point cloud vs original CAD**



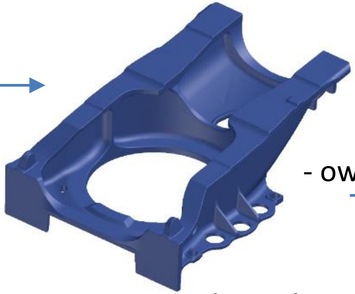
Method 1 Transformed CAD vs actual scanned point cloud



Method 2: Compensated scanned point cloud vs original CAD

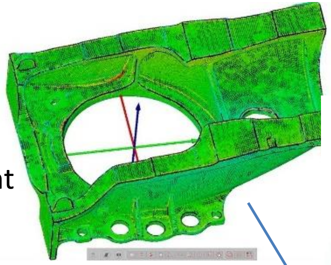


Original mesh from scanned point cloud

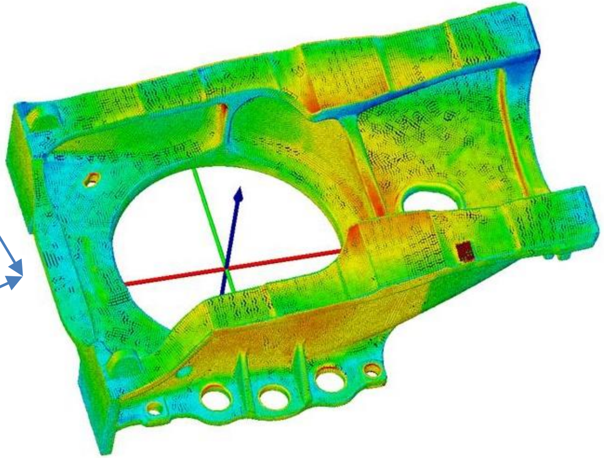


Repaired mesh

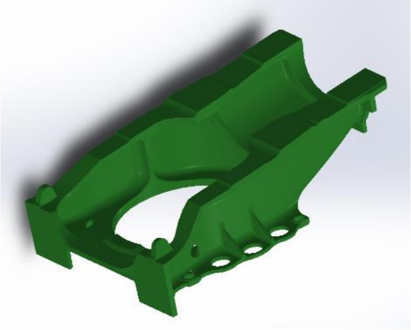
FEM
- own weight



Compensated mesh



Compensated mesh compared to nominal CAD



Nominal CAD

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CURRENT / FUTURE DEVELOPMENTS:

- Very large scale photogrammetry:
  - Antennas
  - Telescope frames
  - Photogrammetry network design simulation
- Characterization and compensation of thermo-mechanical effects in measurements

New advances in metrology of large parts

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