IAPG
Institute for
Applied Photogrammetry
and Geoinformatics

DENKMAL3D

JADE UNIVERSITY
OF APPLIED SCIENCES
Wilhelmshaven Oldenburg Elsfleth

Evaluating Interior Orientation Estimability in Multimedia Photogrammetry

A practical guide on object-invariant bundles

Robin Rofallski, Amandine Colson & Thomas Luhmann

3D Underwater Mapping from Above and Below

Vienna, 10 July 2025

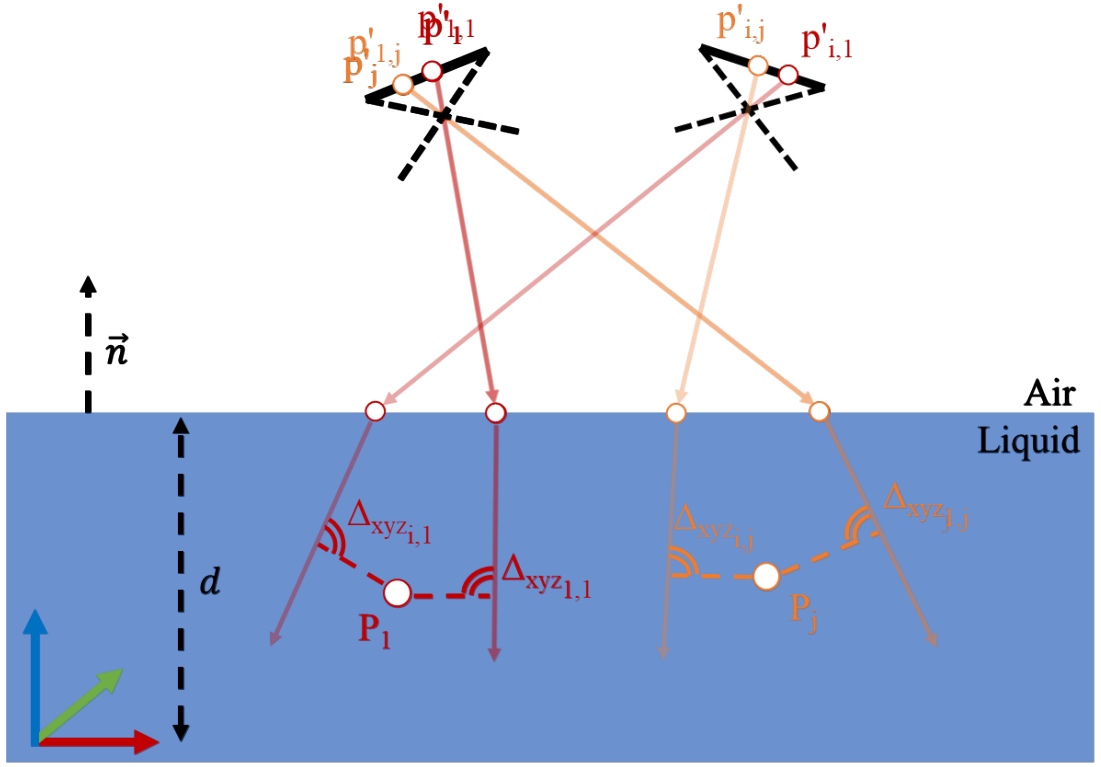
MOTIVATION - MULTIMEDIA PHOTOGRAMMETRY

Ray tracing

- Refraction occuring at liquid interface
- Bundle adjustment can be extended to account for refraction
  - Pinhole camera + refraction parameters
  - Approach by Rofallski et al. (2024)
    - Findings applicable to other approaches
- Considering object-invariant interfaces

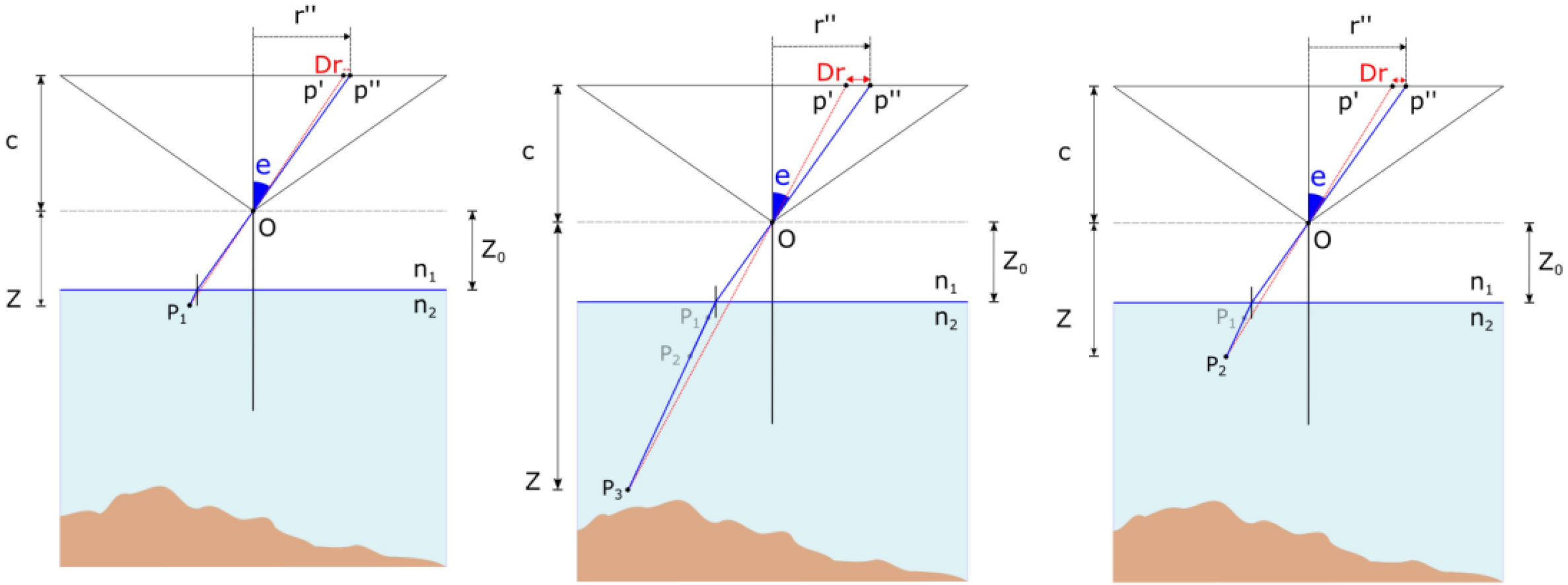
Problem

Correlations between refraction parameters and interior orientation



Rofallski, R.; Colson, A.; Luhmann, T. (2024): Multimedia Photogrammetry for Automated 3D Monitoring in Archaeological Waterlogged Wood Conservation. In: Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci. XLVIII-2-2024, S. 355–362. DOI: 10.5194/isprs-archives-XLVIII-2-2024-355-2024.

MOTIVATION - CORRELATIONS



Nocerino et al. (2021)

Nocerino, E.; Menna, F.; Gruen, A.. (2021): BUNDLE ADJUSTMENT WITH POLYNOMIAL POINT-TO-CAMERA DISTANCE DEPENDENT CORRECTIONS FOR UNDERWATER PHOTOGRAMMETRY. In: Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci. XLIII-B2-2021, S. 673–679. DOI: 10.5194/isprs-archives-XLIII-B2-2021-673-2021.

Research questions

- How do different bundle geometries affect **correlations** and **numerical stability** regarding
  - water depth
  - surface tilt
  - parameter set selection

  …in **multimedia** bundle adjustment?

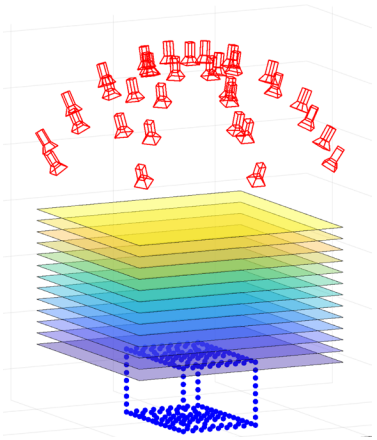
- Which statistical metrics best diagnose problematic configurations?

- What workflow should be followed for robust parameter estimation?

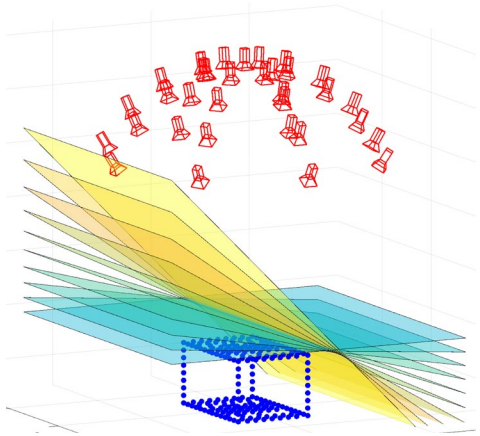
Simulation with optimum configuration

- Single camera
- Semi-spherical bundle configuration
- 132 images
- 25,000 observations
- Zero noise

→ Correlation analysis



Surface height variation

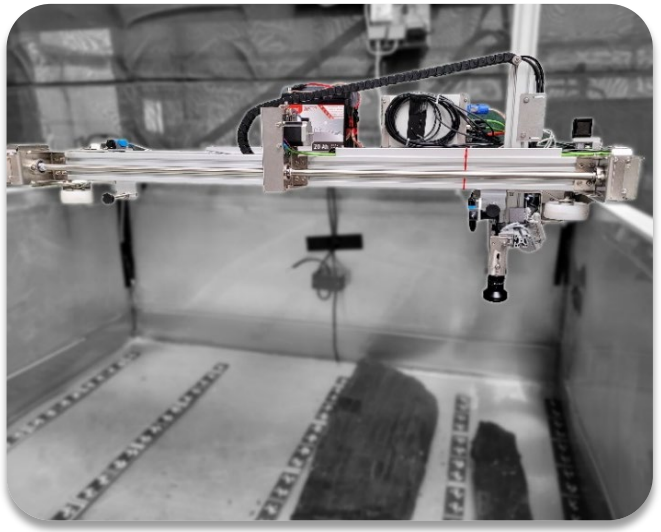


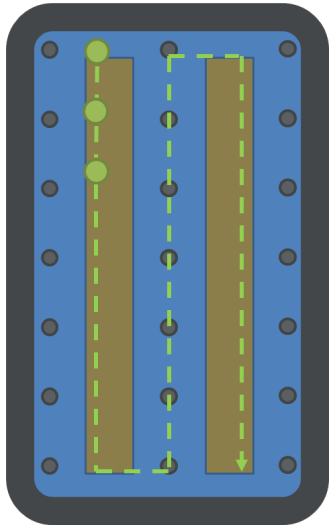
Surface tilt variation

Real world example

- Wood conservation monitoring system
  (Rofallski et al., 2024)
- Stereo system
- „Aerial-triangulation-like“
- 908 images
- 16,000 observations

→ Quality analysis and workflow





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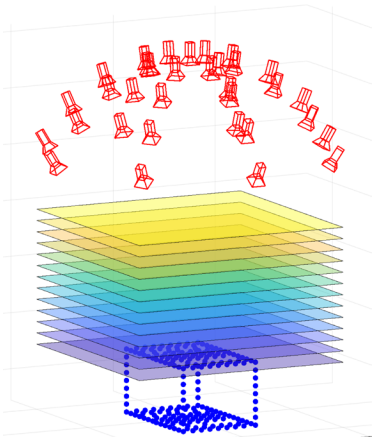

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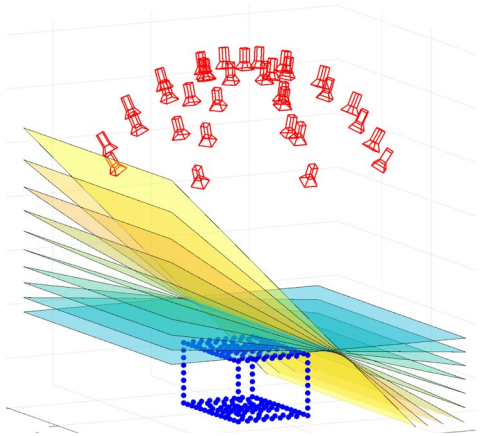

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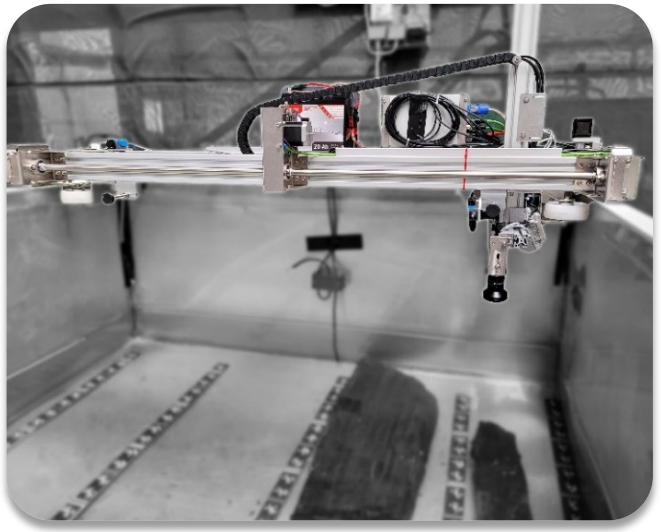
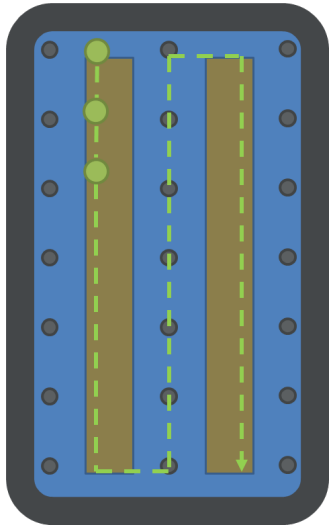
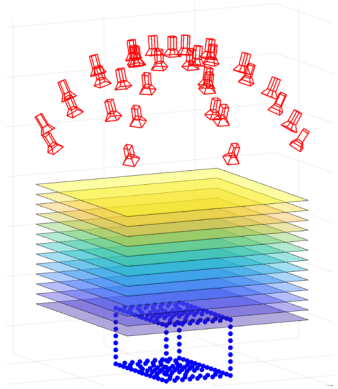
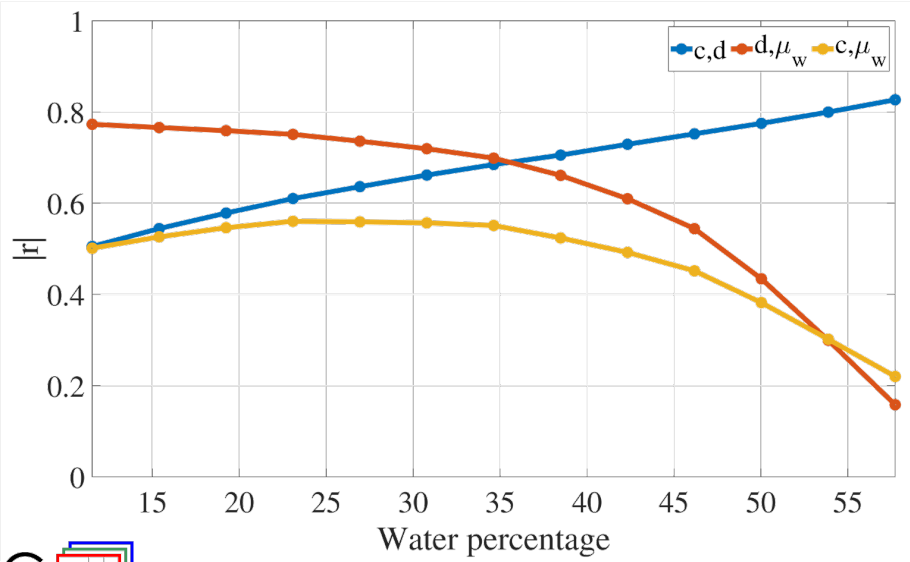




SIMULATION - CORRELATION ANALYSIS

Surface height variation





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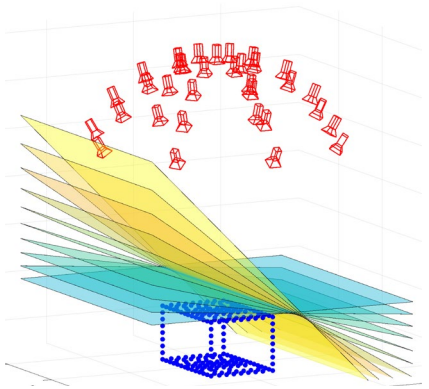

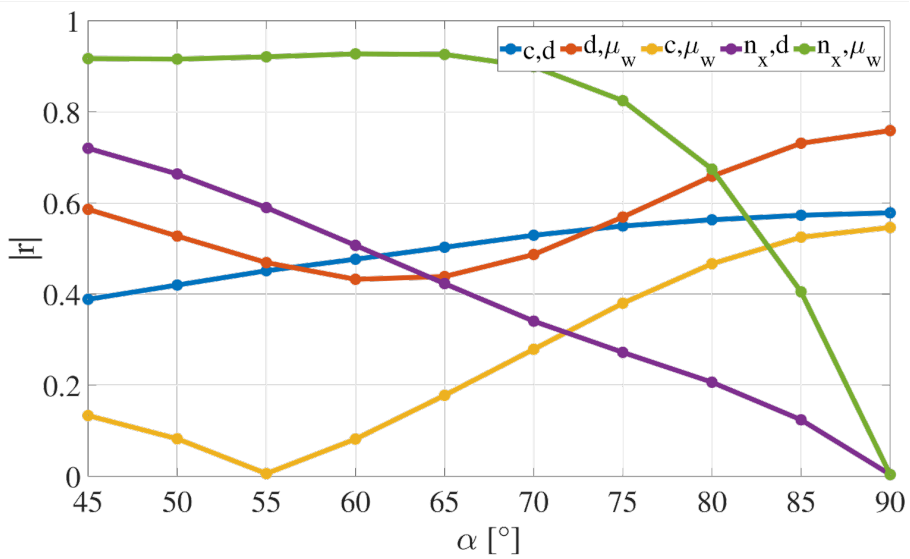

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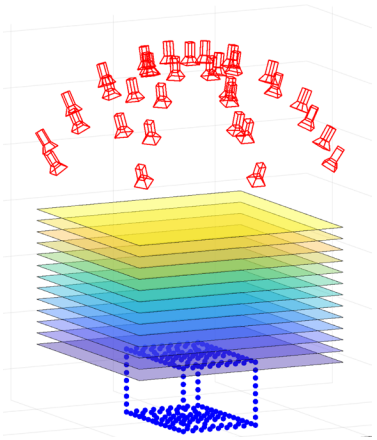

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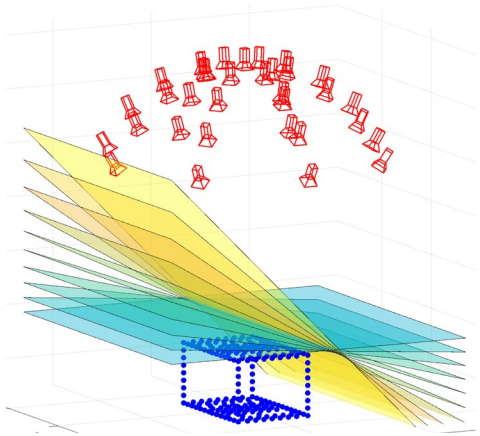

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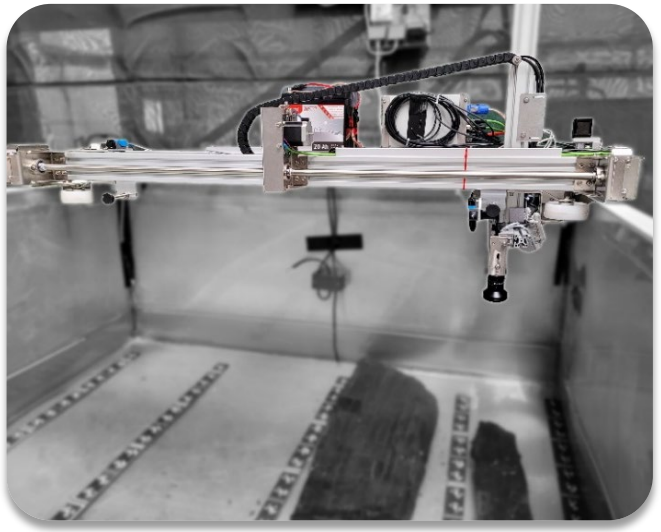
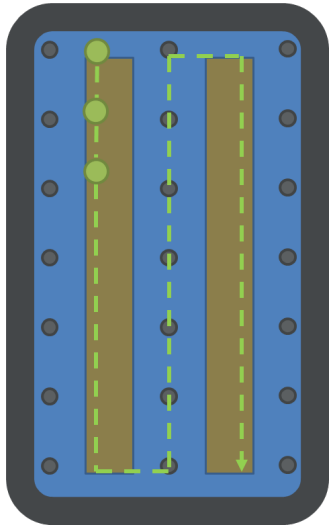
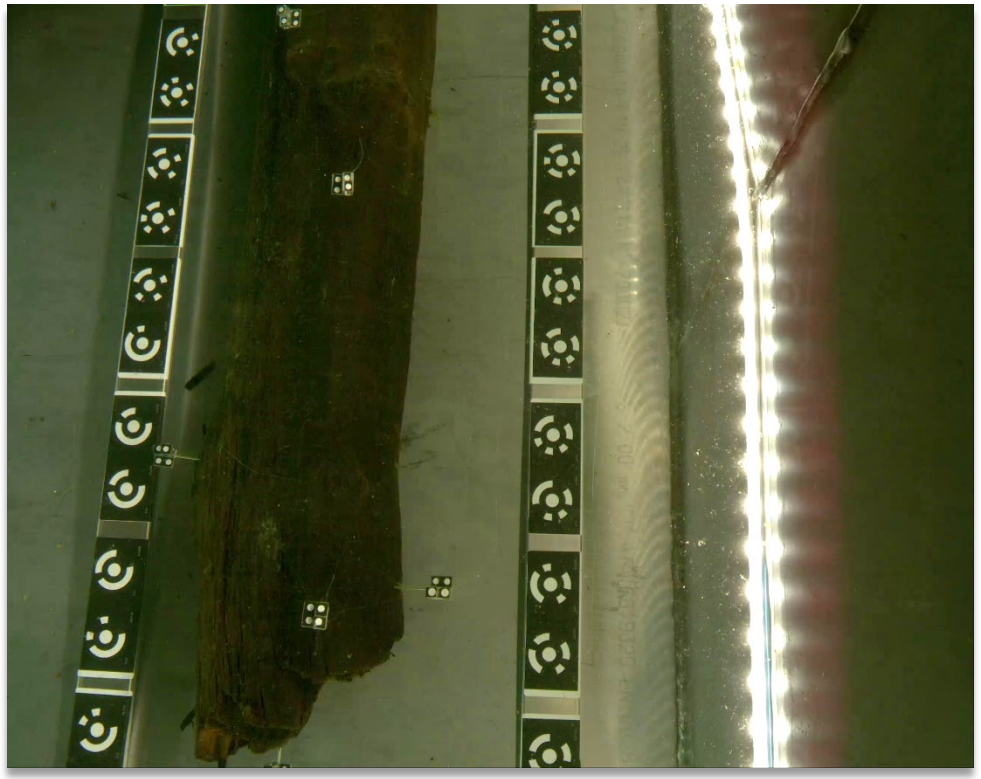




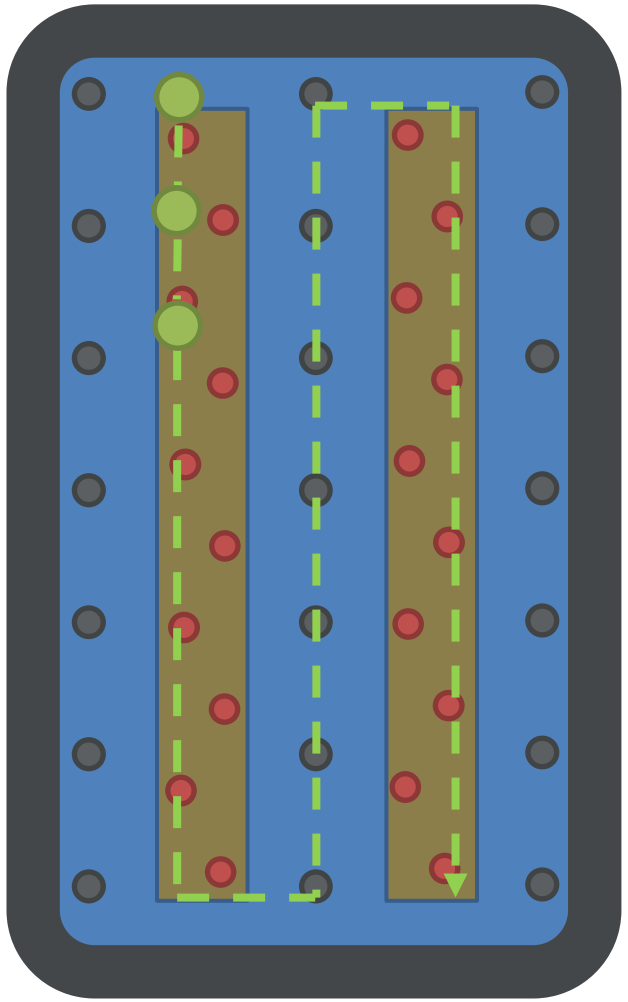
SETUP – BUNDLE GEOMETRY

Bundle geometry

- Meandering over ground
- 80/80 overlap
- 454 images per camera
- No height or rotation variation
- Covered area: 3 x 1.5 m²
- Pre-calibrated cameras

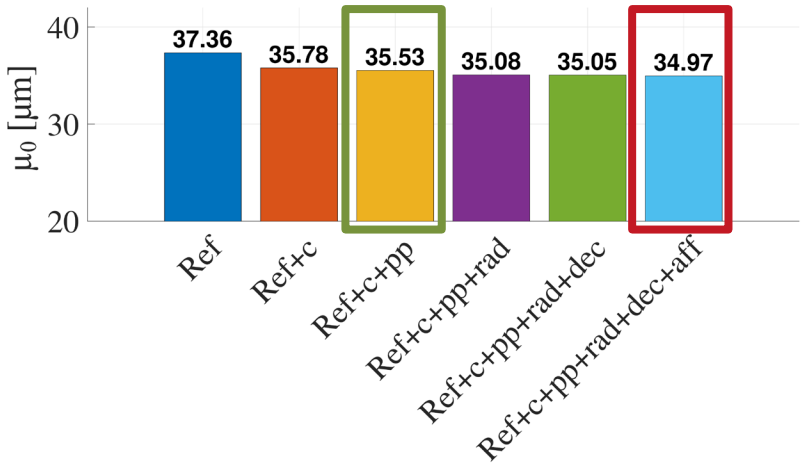


Top view

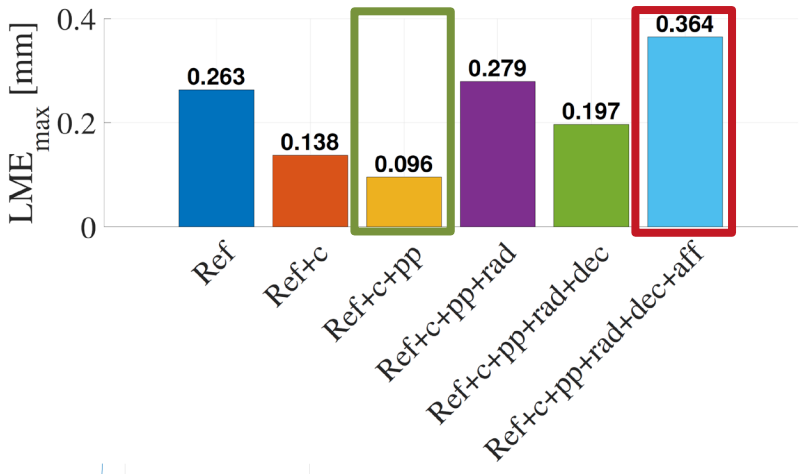


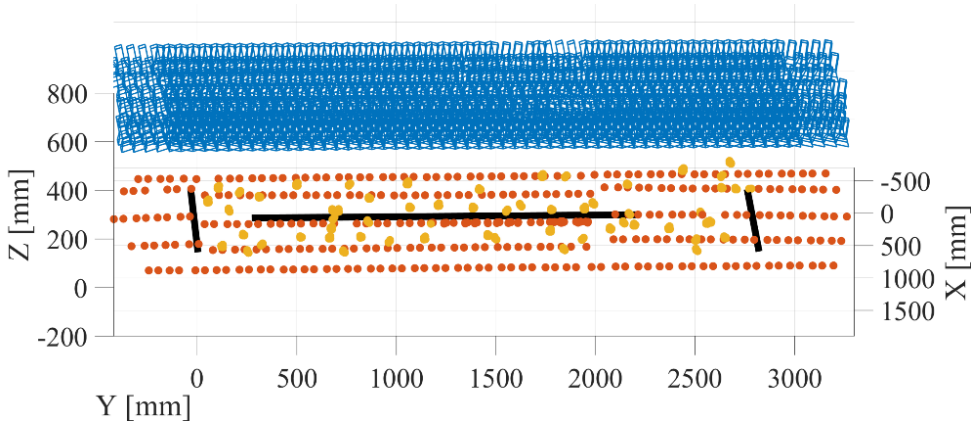
REAL WORLD EXAMPLE

Standard deviation of unit weight
(object space)

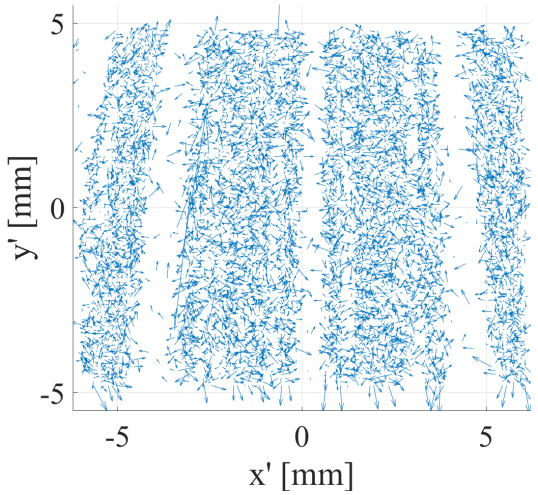


Length measurement error (LME)
CFRP scale bars

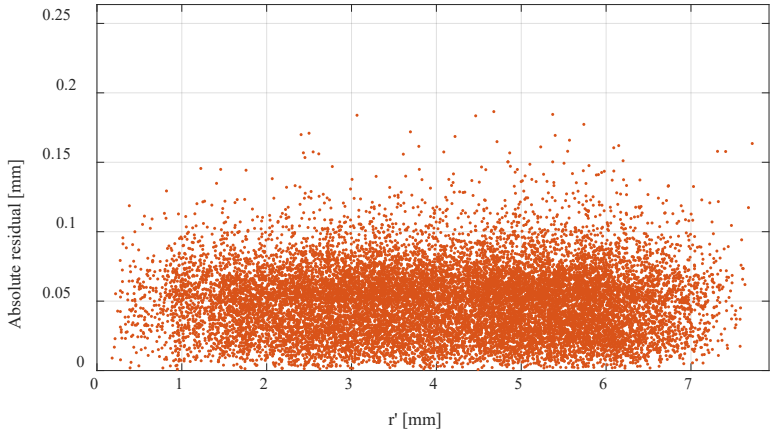




Geometry



Residual distribution



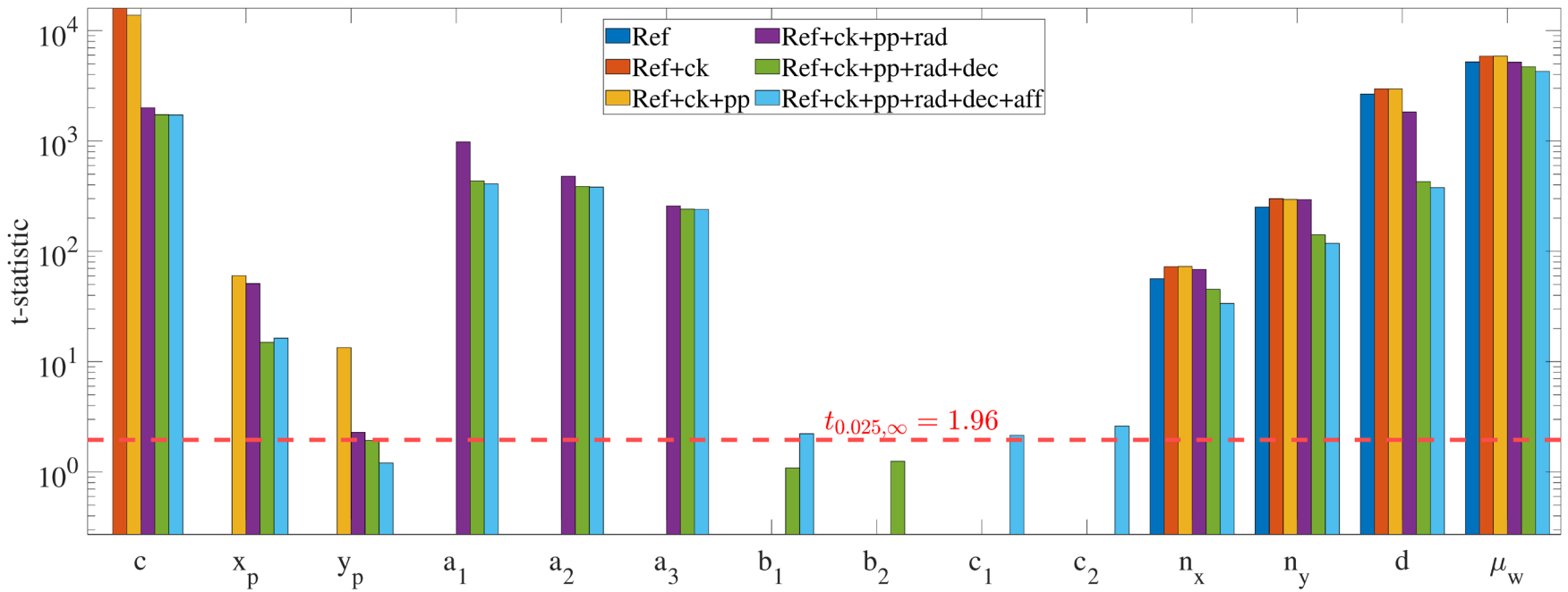
Absolute residuals

Student‘s t-test

- Reveals significance of parameters at chosen level of significance (e.g. 95%)

→ Adjustment for decentering distortion and affinity/shear appear suspicious

$$t_i = \frac{x_i}{\sigma_i}$$

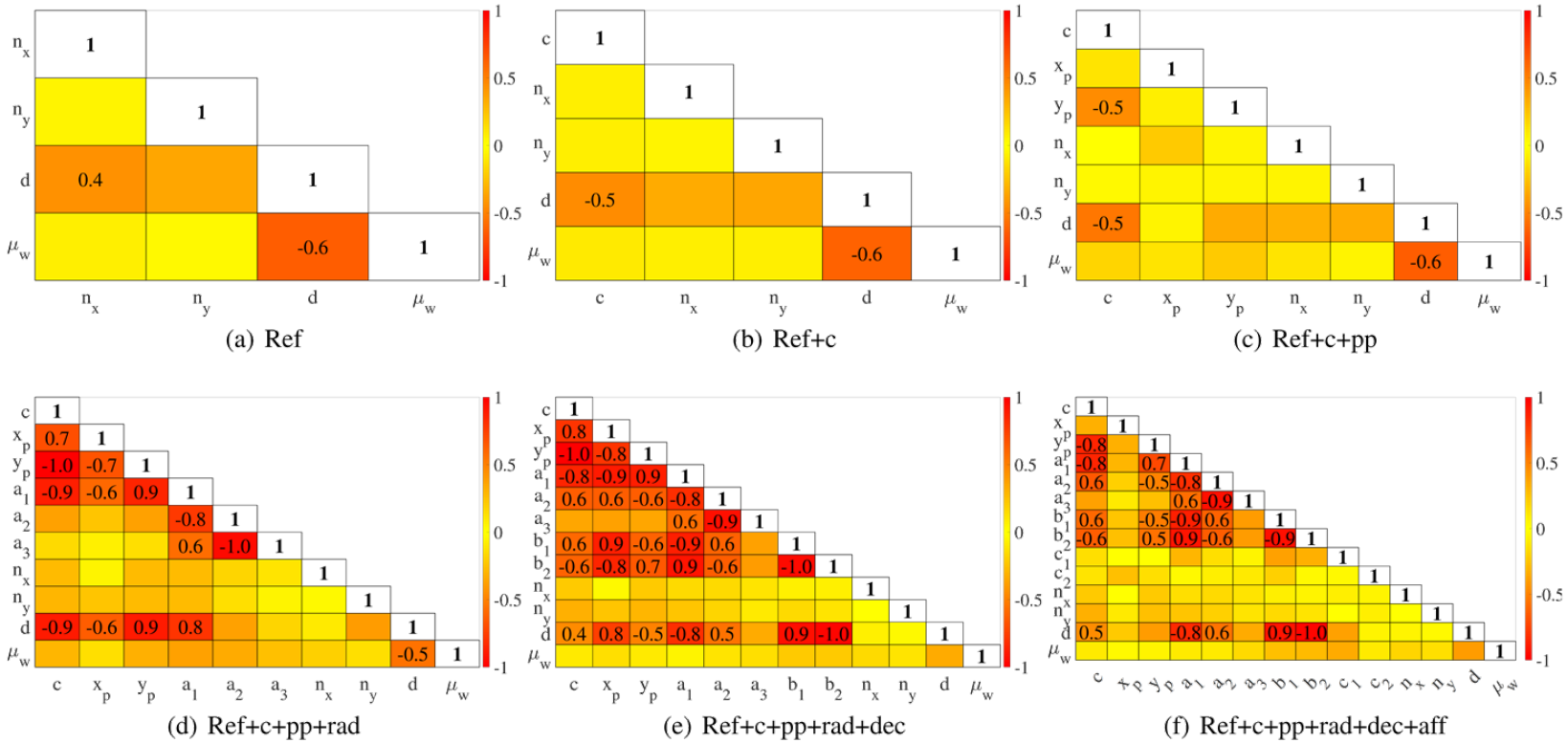


Correlation matrices

- Reveals correlations of parameter pairs
- No absolute value for problematic settings

→ Radial-symmetric distortion appears problematic, too

$$r_{i,j} = \frac{\Sigma_{\mathrm{xx_{i,j}}}}{\sqrt{\Sigma_{xx_{i,i}} \cdot \Sigma_{xx_{j,j}}}}$$

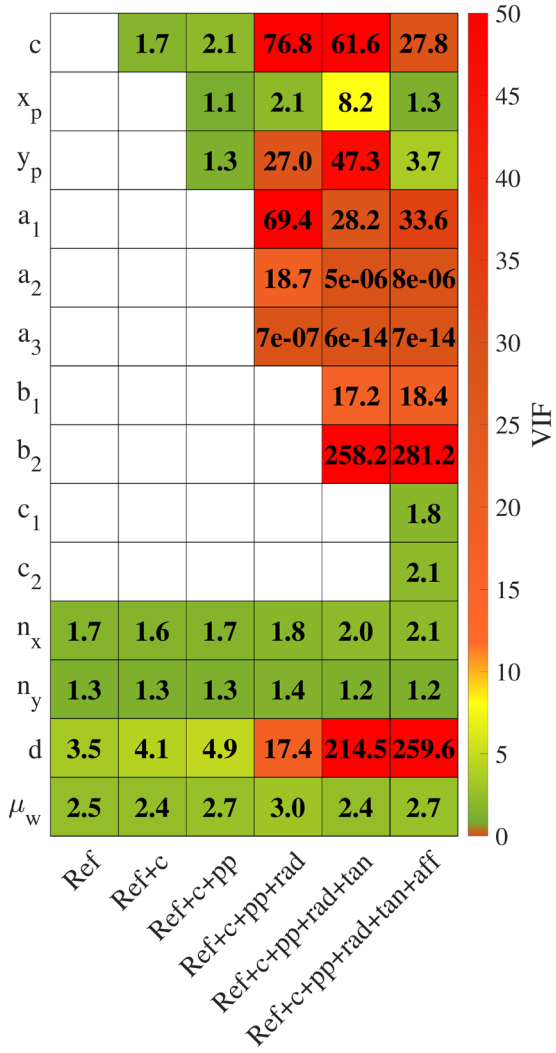


Variance Inflation Factors

- Reveals measure of explainability of parameter by other parameters
  - VIF < 5: No problematic correlations expected
  - 5 < VIF < 10: Increased correlations
  - 10 < VIF: Problematic correlations or instable bundle
  - VIF << 1: Instable bundle

→ Clear indication of radial-symmetric adjustment

$$VIF_i = N_{i,i} \cdot Qx_{i,i}$$



CONCLUSION

Summary

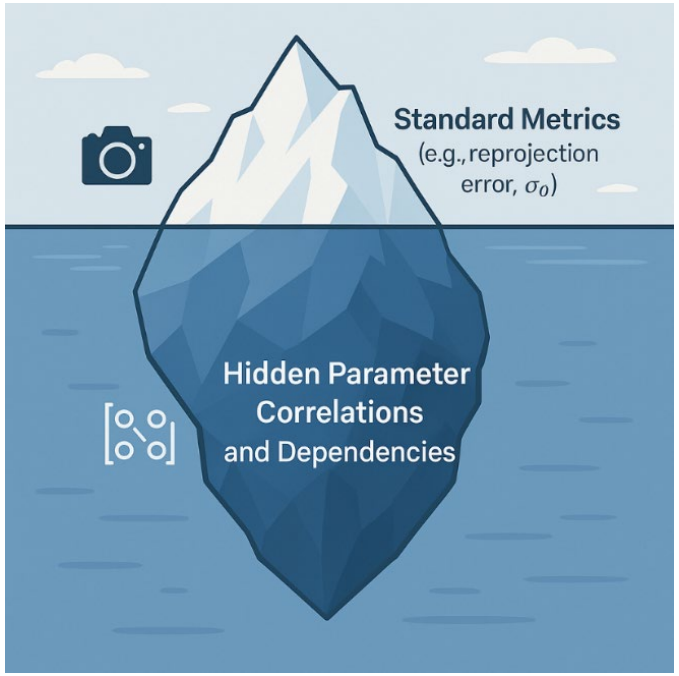
- Simulations show inevitable correlations - even with good geometry
- Real world example shows pitfalls

Conclusion

- Multimedia bundles need to be configured properly
- Analysis on the results should be carried out thoroughly
  - Independent ground truth
  - Statistical tests, correlations, VIF, …
- Necessary parameters not always available in commercial software

Outlook

- Small subset of possible configurations – more analyses necessary
- Know your dependencies – and try to resolve them properly



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