Benchmarking automatic bundle adjustment results

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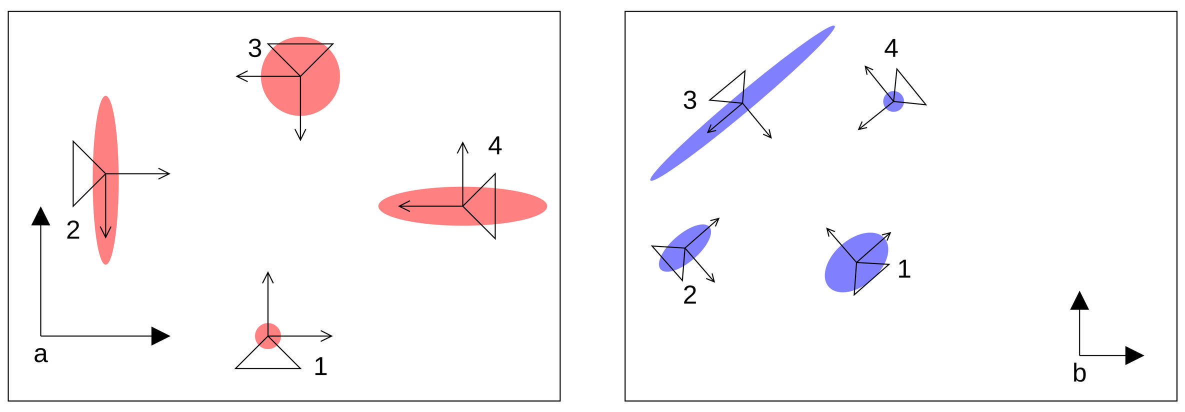
Motivation

- In classical photogrammetry, evaluations of bundle adjustments are based on 3D points
- Automatic methods yield 2 problems for the evaluation:
  1. The choice of points differs for each method
  2. Methods often contain random components (i.e. RANSAC)
- Following Pennec and Thirion (1995), we conclude:
  1. Use the orientation parameters for benchmarking
  2. Benchmark against a reference dataset

Overview of the benchmarking approach

Given 2 sets of corresponding orientation parameters in arbitrary coordinate systems $\{{}^a\mathbf{d}_1, {}^a\Sigma_{d_1d_1}\}$ and $\{{}^b\mathbf{d}_2, {}^b\Sigma_{d_2d_2}\}$



(ellipses denote uncertainties)

Derive the following measures:

- **consistency** c of form deviation and internal precision
- **precision level** p related to a reference dataset

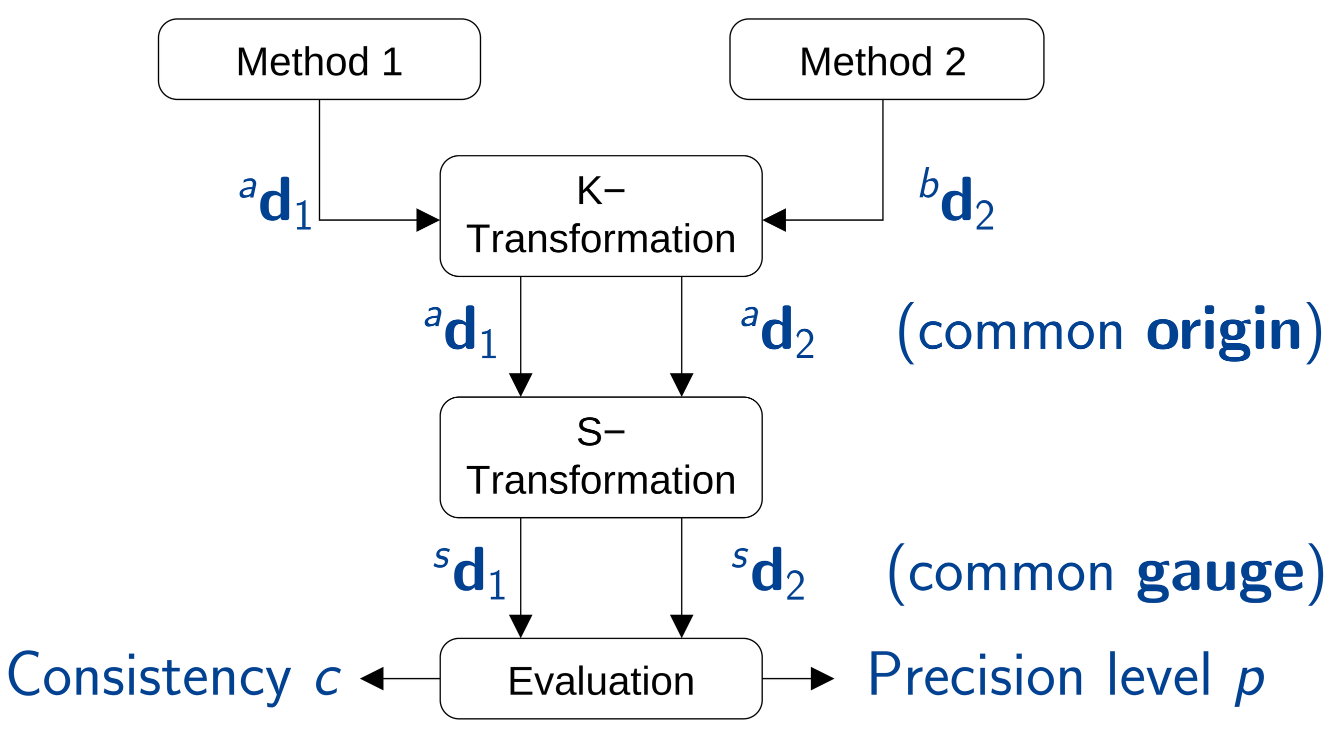
For methods with random components also derive

- the **sample consistency** c_s over repeated estimates

Benchmark test: For $2 \leq i \leq M$ methods, compute all three measures. Require a valid range of c_{s_i}, then report c_i and p_i w. r. t. the same reference dataset.

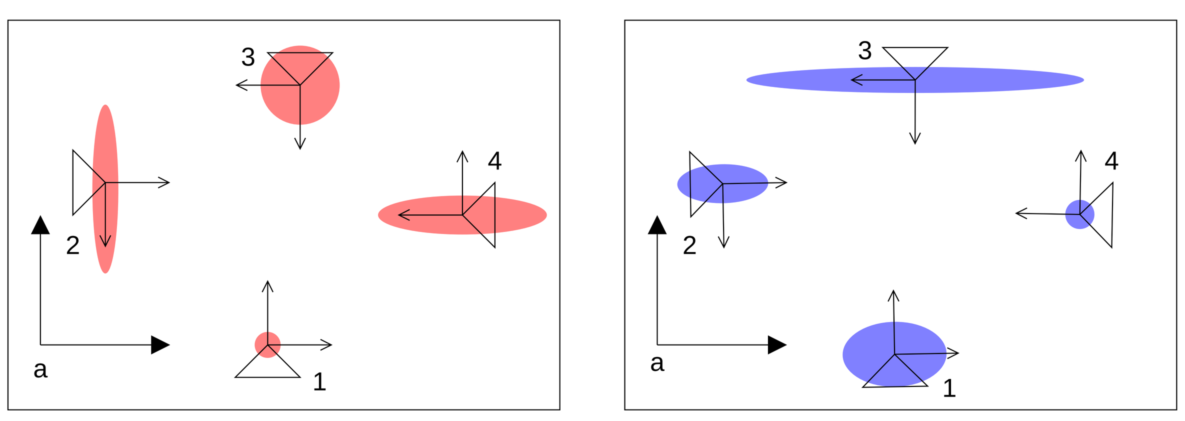
Parameter transformations

- **Gauge problem:** For comparison, the datasets have to be transformed to a well-defined coordinate system s.
- **Solution:** Derive K- and S-transformations (Baarda, 1967; Molenaar, 1981) for sets of orientation parameters



(1) K-transformation

- Estimate a similarity transformation $K(\mathbf{t}_K, \mathbf{q}_K, \lambda_K)$ between ${}^a\mathbf{d}_1$ and ${}^b\mathbf{d}_2$ that brings ${}^b\mathbf{d}_2$ into system a
- Update ${}^b\Sigma_{d_2d_2}$ using linear error propagation. Observe from the ellipses that **the gauge still differs**!



(2) S-transformation

- A differential non-stochastic similarity transformation into a well-defined coordinate system s

$${}^s\mathbf{d}_{in} = \Delta S \circ {}^a\mathbf{d}_{in} \qquad i = \{1, 2\}$$

- Define weight matrix W_s and use

$${}^sS = I - A(A^\mathsf{T} W_s A)^{-1} A^\mathsf{T} W_s$$

to obtain the S-transformation for both datasets

$${}^s\mathbf{d}_i = {}^sS\ {}^a\mathbf{d}_i \qquad {}^s\Sigma_{d_id_i} = {}^sS\ {}^a\Sigma_{d_id_i}\, {}^sS^\mathsf{T} \quad i = \{1, 2\}$$

- The Jacobian A is derived in Dickscheid et al. (2008)
- ${}^s\mathbf{d}_1$ and ${}^s\mathbf{d}_2$ **share the same gauge now**

Consistency c

- Interpretation: Form deviation of corresponding orientation parameters w. r. t. their internal precision.
- c is based on the Mahalanobis distance:

$$c^2 = \frac{|{}^s\mathbf{d}_1 - {}^s\mathbf{d}_2|_{({}^s\Sigma_{d_1d_1} - {}^s\Sigma_{d_2d_2})}}{R} \sim F_{R,\infty}$$

assuming ${}^s\Sigma_{d_1d_1}$, ${}^s\Sigma_{d_2d_2}$ uncorrelated, with $R \hat{=}$dof.

Precision level p

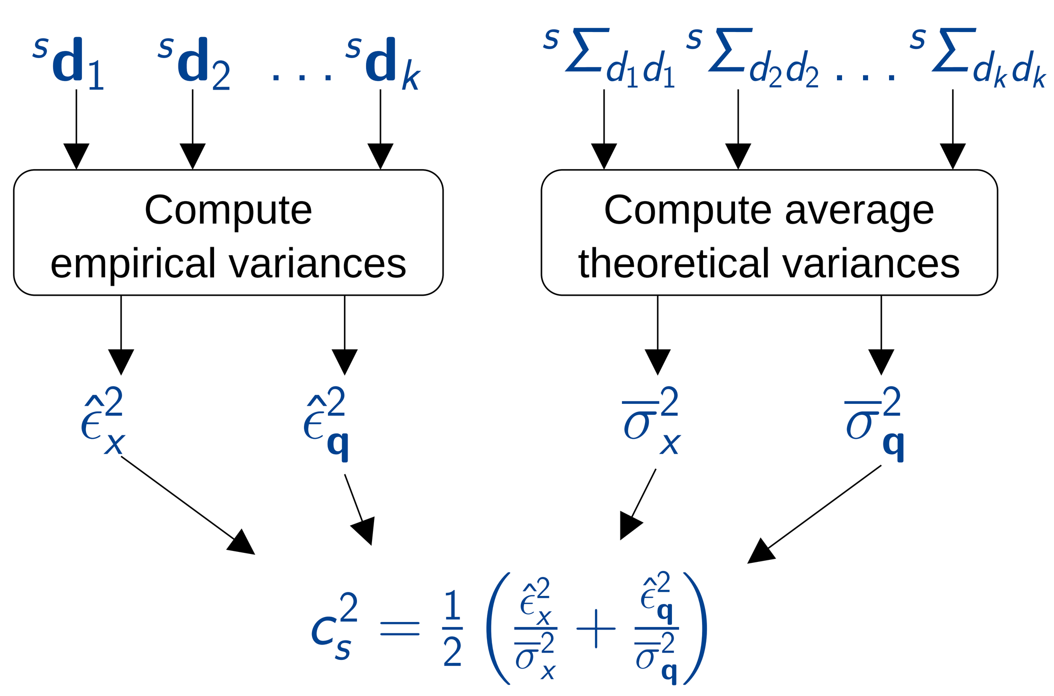
- Interpretation: Distance between two covariance matrices, based on Förstner and Moonen (1999)
- p is derived by computing the generalized eigenvalues r^2 from $|{}^s\Sigma_{d_1d_1} - r^2\ {}^s\Sigma_{d_2d_2}| = 0$ to get

$$p := e^{\sqrt{\ln r^2}} \geq 1$$

- p is the average quadratic deviation of the ratio of standard deviations from 1.

Sample consistency c_s

- Interpretation: Consistency of the variation in orientation parameters w. r. t. their average internal precision
- Compute K repeated estimates under identical conditions, i. e. yielding K sets $\{{}^a\mathbf{d}_k, {}^a\Sigma_{d_kd_k}\}$
- Again, c_s is derived after applying the K- and S-transformation on all K sets



References

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