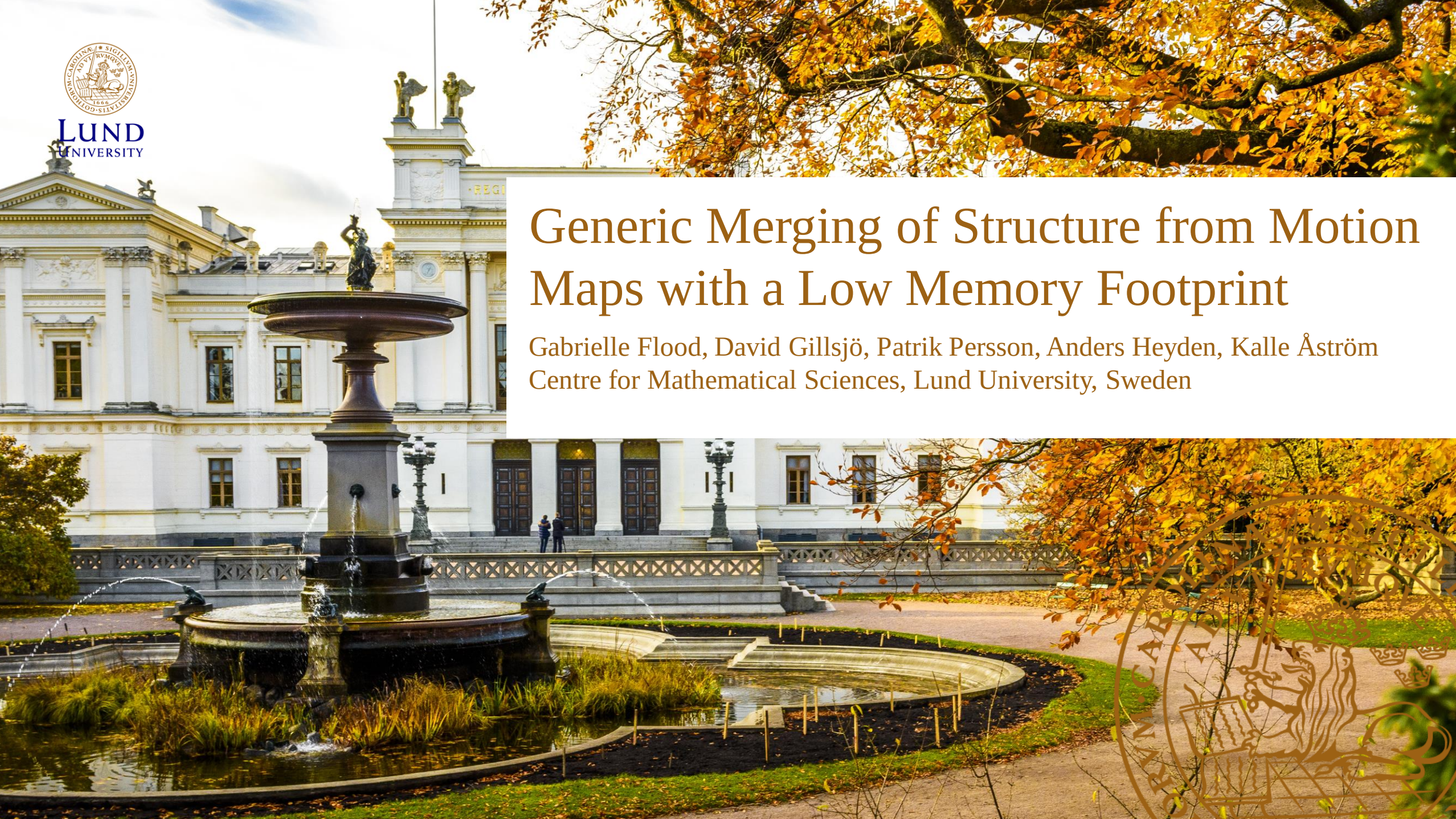

Generic Merging of Structure from Motion Maps with a Low Memory Footprint

Gabrielle Flood, David Gillsjö, Patrik Persson, Anders Heyden, Kalle Åström
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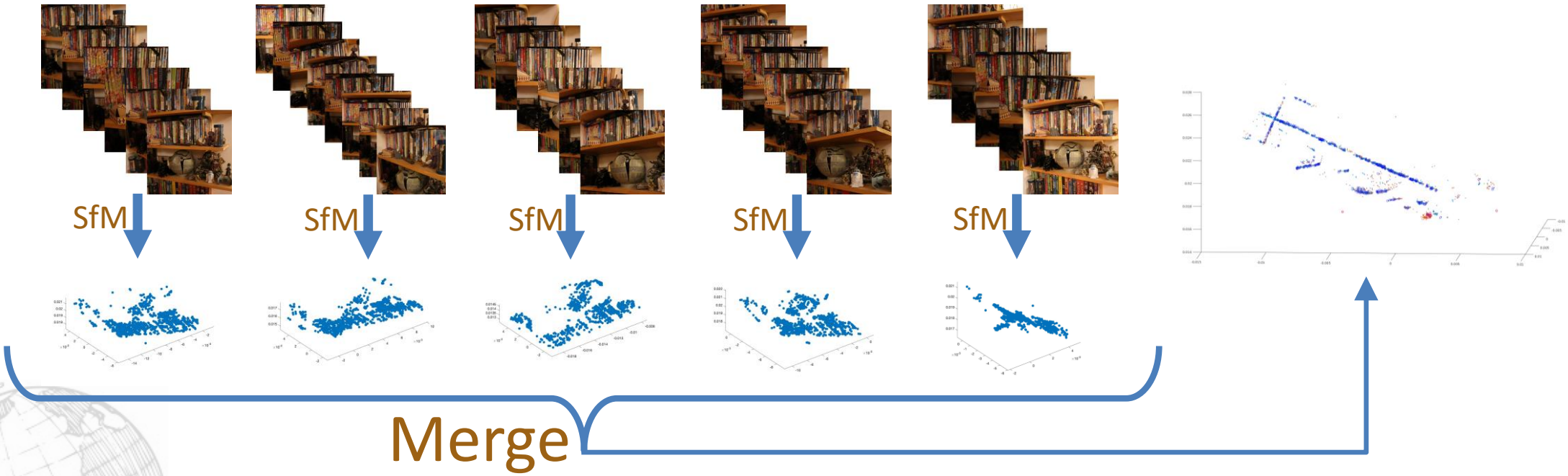
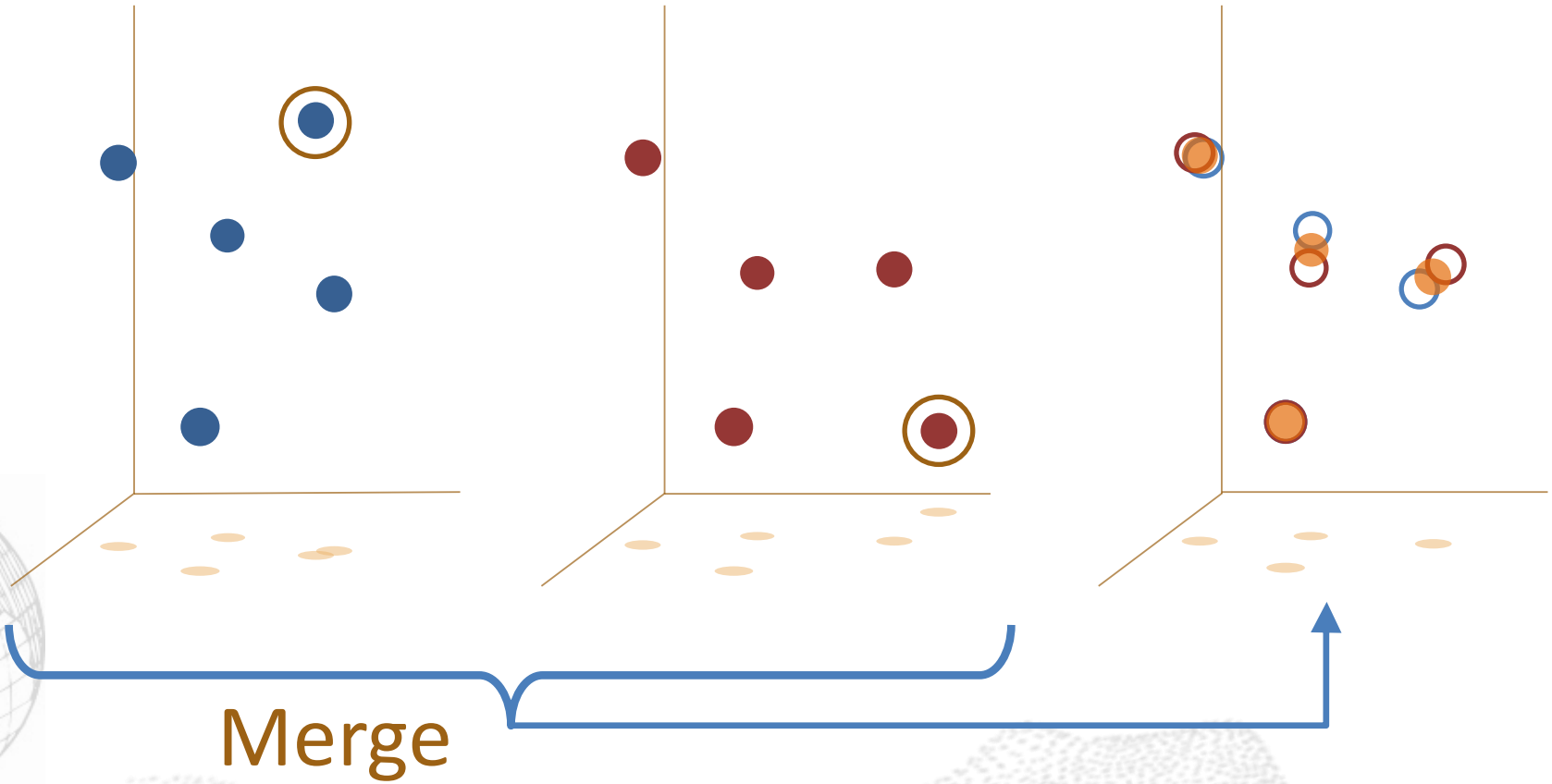
Overview of map merging



Overview of map merging



Compact error representation

For bundle adjustment, collect parameters in ***z***, call residuals ***r*** and the Jacobian *J*

$$\mathbf{z}^* = \text{argmin}_{\mathbf{z}} \mathbf{r}^T \mathbf{r}, \qquad \Delta\mathbf{z} = -(J^T J)^{-1} J^T \mathbf{r} \qquad \Delta\mathbf{z} = \begin{bmatrix} \Delta\mathbf{q} & \Delta\mathbf{s} \end{bmatrix}^T$$

$$J = \begin{bmatrix} J_a & J_b \end{bmatrix}$$

$$\Delta\mathbf{r} = \underbrace{\left(J_a + J_b \cdot \frac{\partial \mathbf{s}}{\partial \mathbf{q}} \right)}_{J_q} \Delta\mathbf{q}, \qquad \frac{\partial \mathbf{s}}{\partial \mathbf{q}} = -(J_b^T J_b)^{-1} (J_a^T J_b)^T$$

$$\mathbf{r}^T \mathbf{r} \approx a^2 + \Delta\mathbf{q}^T R^T R \Delta\mathbf{q}$$

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Our merging approach

$$\mathbf{w} = (\mathbf{q}, T_1, T_2, \ldots, T_N)$$

$$\mathbf{r}^T\mathbf{r} \approx \hat{\mathbf{r}}^T\hat{\mathbf{r}}$$

$$\hat{\mathbf{r}} = \begin{bmatrix} a^{(1)} \\ R^{(1)}(T_1 p_1(\mathbf{q}) - \mathbf{q}^{(1)}) \\ \vdots \\ a^{(N)} \\ R^{(N)}(T_N p_N(\mathbf{q}) - \mathbf{q}^{(N)}) \end{bmatrix}$$

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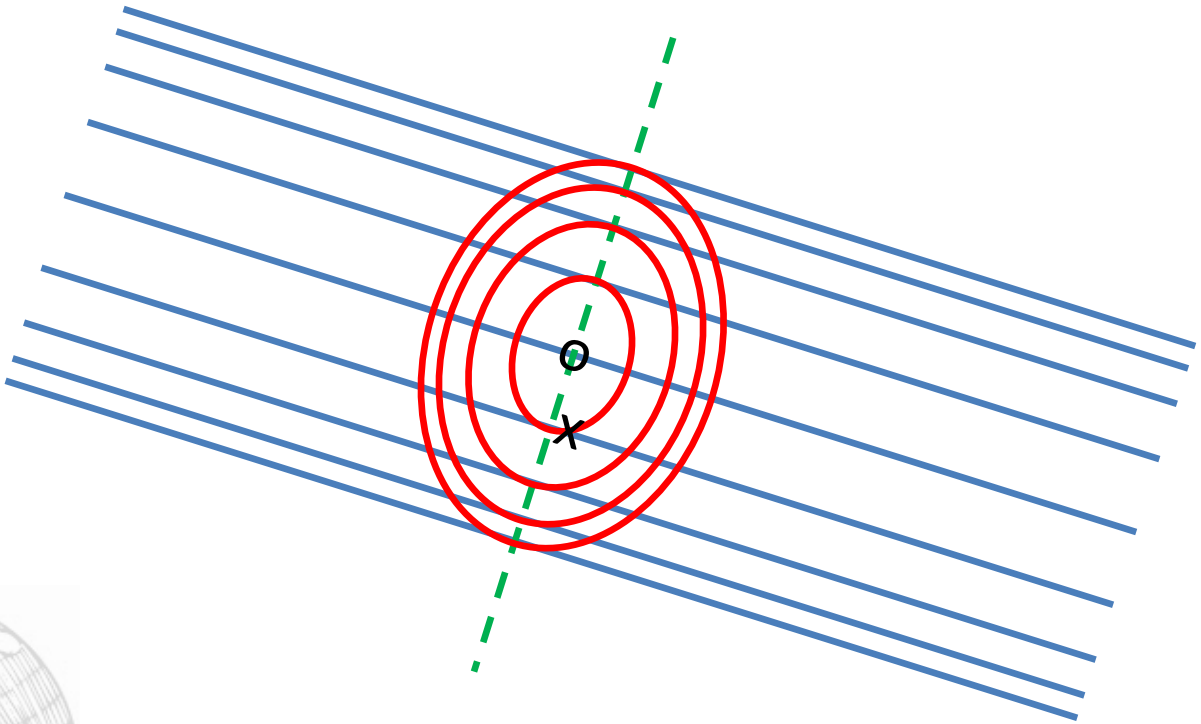
Gauge freedom



- R has a 7-dimensional nullspace due to gauge freedom
- We need to be close to the working point.
- Add perpendicular penalty to make the error function quadratic

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Hypothesis testing

$$\mathbf{E}\Big[\underbrace{\bar{a}^2 - \sum_k \left(a^{(k)}\right)^2}_{\tilde{a}}\Big] = \sigma^2\Big(\eta_{res} - d_{dof} - \textstyle\sum_k \left(\eta_{res}^{(k)} - d_{dof}^{(k)}\right)\Big)$$

$$\mathbf{E}[\tilde{a}] = \sigma^2\Big(\textstyle\sum_k d_{dof}^{(k)} - d_{dof}\Big) = \sigma^2\left(\left(\sum_{i=1}^{N} 3\kappa_i(i-1)\right) - 7\cdot(N-1)\right)$$

$$f_{\alpha,\nu}(x) = \frac{1}{\Gamma(v)}\alpha^\nu x^{\nu-1}\mathrm{e}^{-\alpha x} \qquad \alpha = \frac{1}{2\sigma^2}, \quad \nu = \frac{\left(\sum_{i=1}^{N} 3\kappa_i(i-1)\right) - 7\cdot(N-1)}{2}$$

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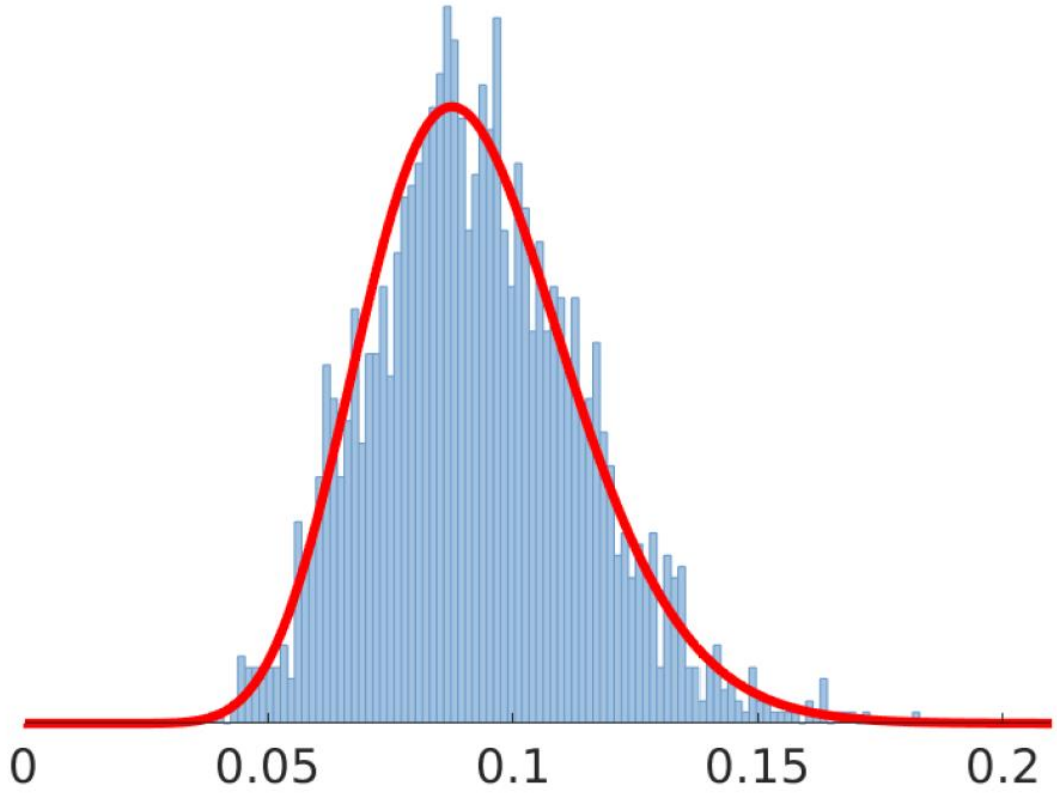
Hypothesis testing



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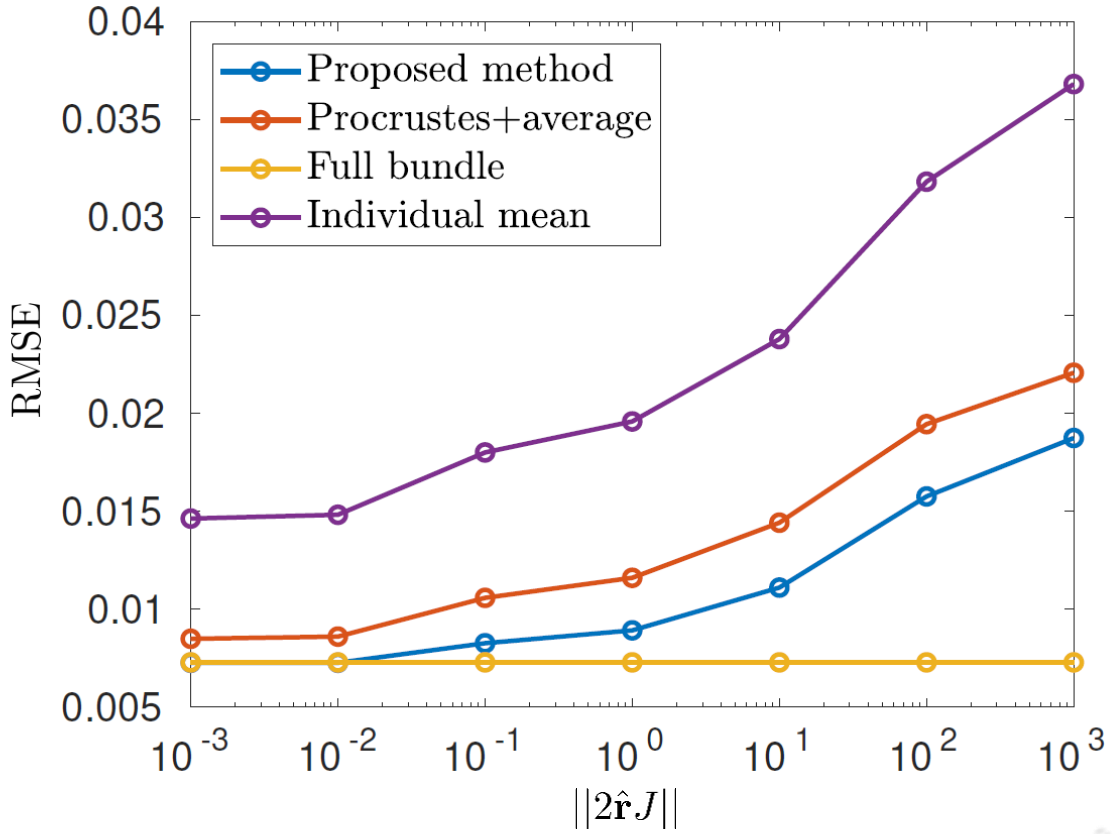
Early stopping of pre-processing

- We stopped the individual bundles at different values of the norm of the gradient
- The RMSE of the individual maps and the merged maps were computed
- Merging was done using
  - the proposed method
  - Procrustes + averaging
  - one large bundle



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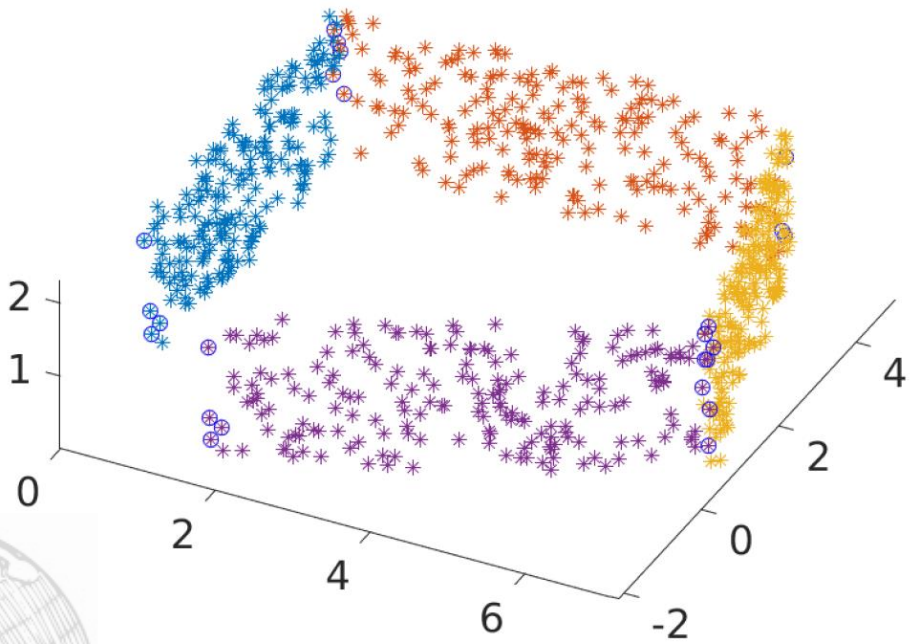
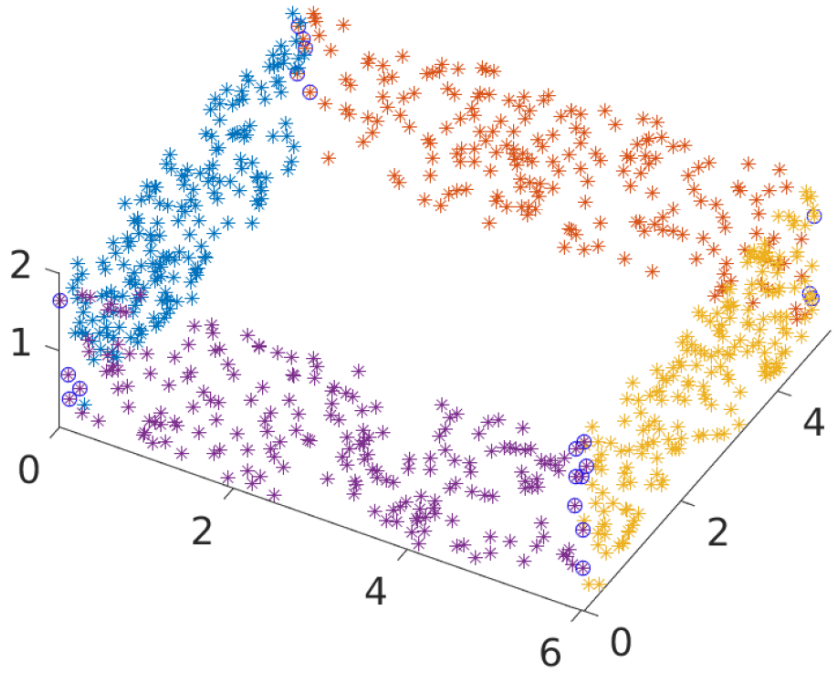
Loop closure for simulated data





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Experiment in an office: data

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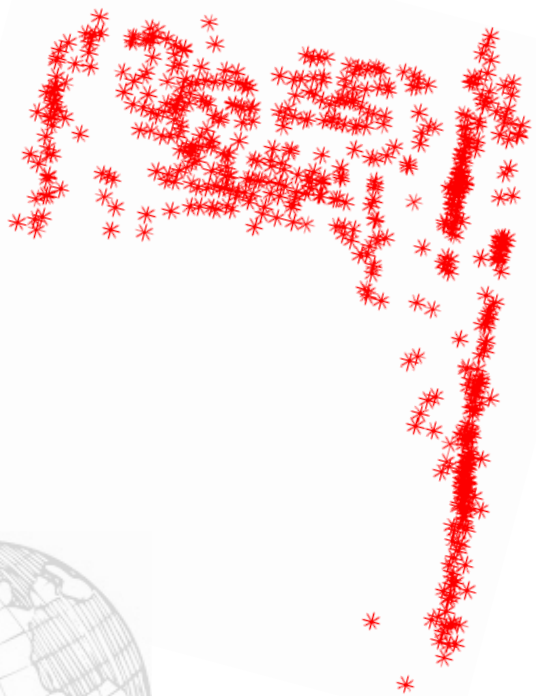

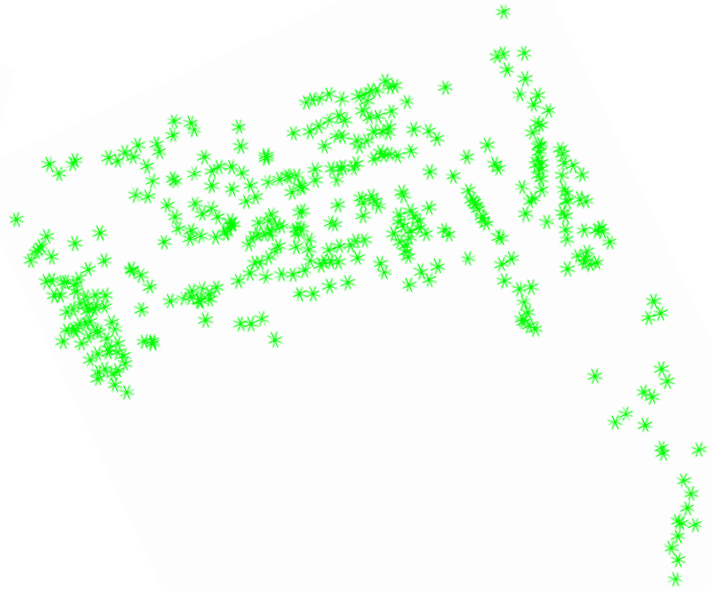

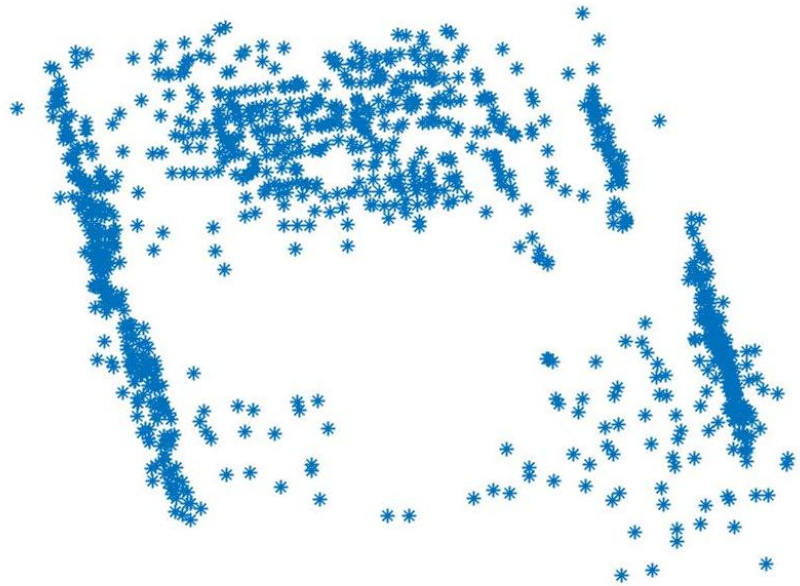

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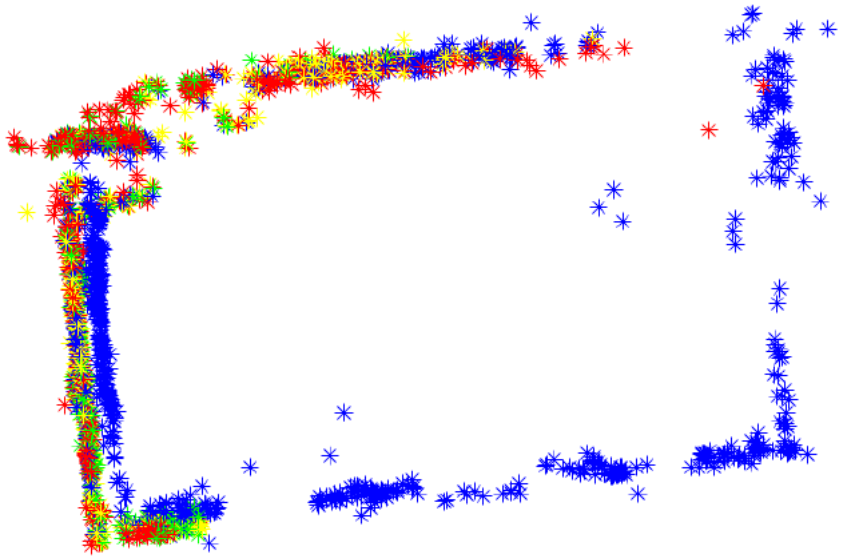
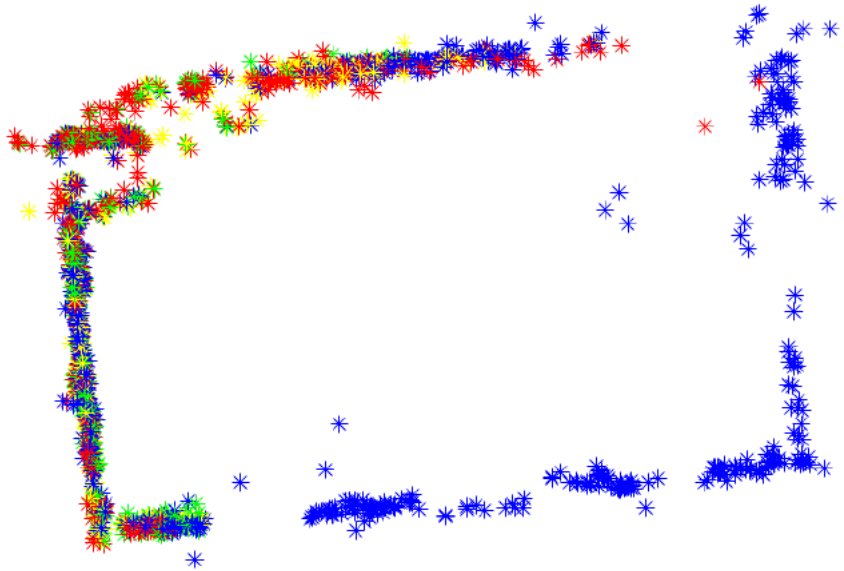
Experiment in an office: result

Procrustes + averaging



Bundle over linearised error



Experiment in an office: evaluation

Pt 1 ind	Pt 2 ind	Dist (mm) one map	Dist (mm) merge Pro.	Dist (mm) merge our	Dist (mm) gt
52	766	365	365	220	213
52	839	589	589	512	516
52	840	1358	1296	1264	1260
60	839	825	825	834	840
60	840	879	1023	860	857

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Experiment in an office: evaluation

Bundle session	# points	Size of full Jacobian	Size of compressed Jacobian
1	999	$18\,918 \times 3\,621$	72×72
2	603	$11\,972 \times 2\,151$	72×72
3	549	$11\,114 \times 1\,989$	72×72
4	386	$7\,596 \times 1\,452$	72×72
merge	2465	$49\,600 \times 8\,997$	288×100

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