Camera Uncertainty Computation in Large 3D Reconstruction

Michal Polic and Tomas Pajdla

Previous work

Lhuillier, Maxime, and Mathieu Perriollat. "Uncertainty ellipsoids calculations for complex 3D reconstructions." *ICRA 2006*

Hartley, Richard, and Andrew Zisserman. *Multiple view geometry in computer vision*. Cambridge university press, 2003.

Kanatani, Ken-ichi, and Daniel D. Morris. "Gauges and gauge transformations for uncertainty description of geometric structure with indeterminacy." *IEEE Transactions on Information Theory* 47.5 (2001).

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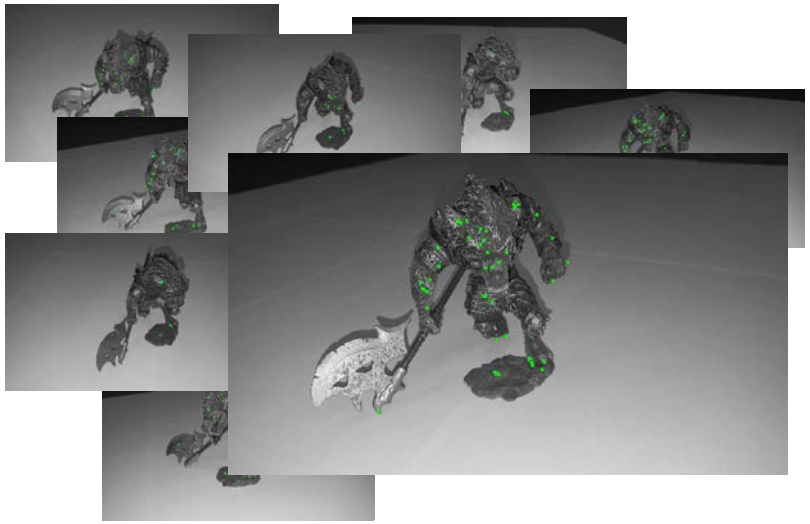
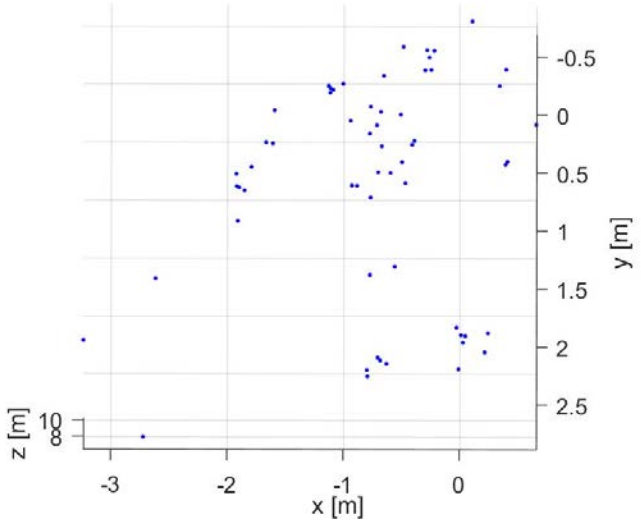
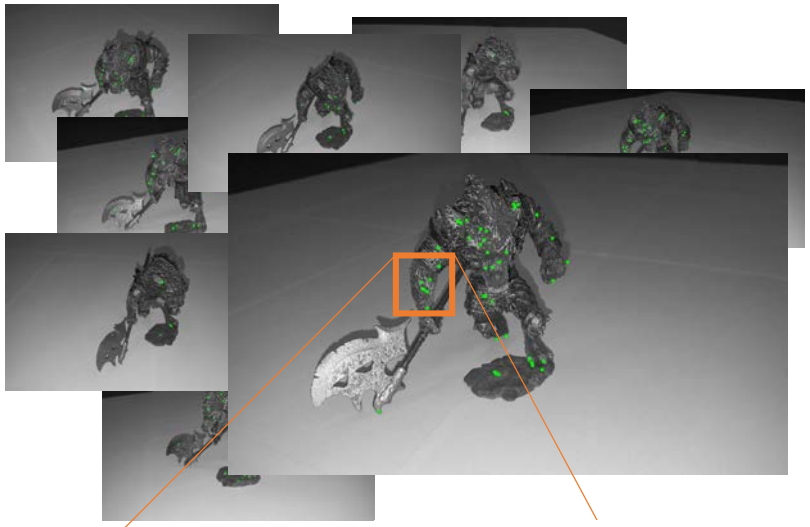
Structure from Motion



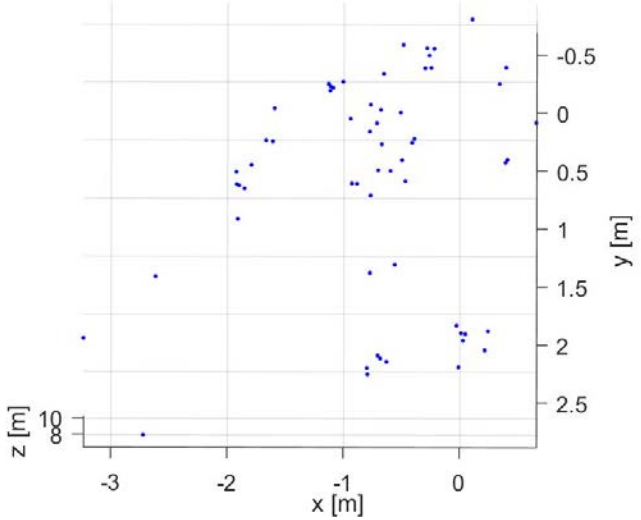


FEATURE POINTS → **PARAMETERS OF 3D SCENE**

Uncertainty propagation

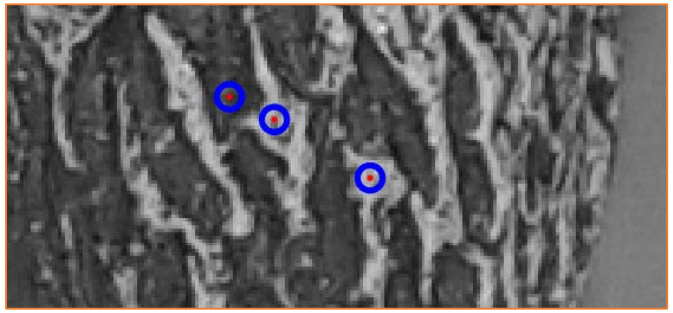


FEATURE POINTS



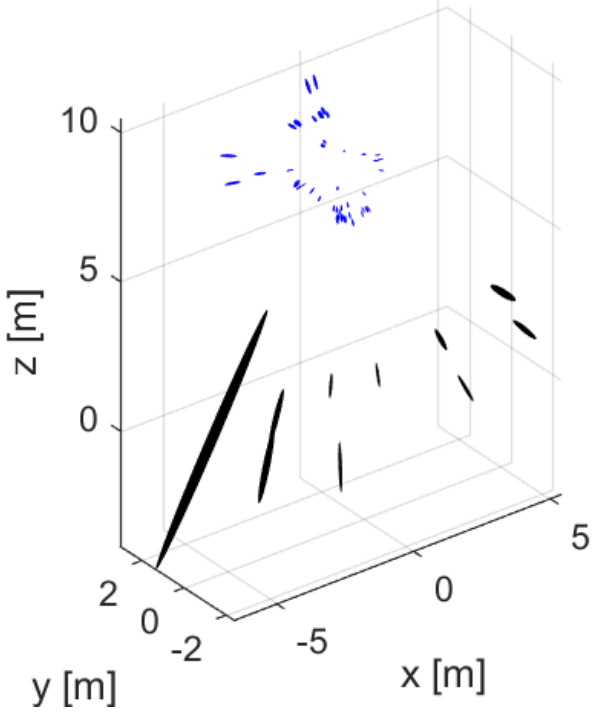
PARAMETERS OF 3D SCENE

COVARIANCE MATRICES OF PARAMETERS OF 3D SCENE



COVARIANCE MATRICES OF FEATURE POINTS

RESIDUAL FUNCTION



Previous work

[KANATANI2001] - Gauges and gauge transformations for uncertainty description of geometric structure with indeterminacy

- Normal form of covariance matrix for 3d scene parameters
- Computationally demanding
- Numerically imprecise

$$\Sigma_\theta = (J^T \Sigma_{\boldsymbol{u}}^{-1} J)^+$$

Previous work

[KANATANI2001] - Gauges and gauge transformations for uncertainty description of geometric structure with indeterminacy

- Normal form of covariance matrix for 3d scene parameters $\Sigma_\theta = (J^T \Sigma_{\boldsymbol{u}}^{-1} J)^+$
- Computationally demanding
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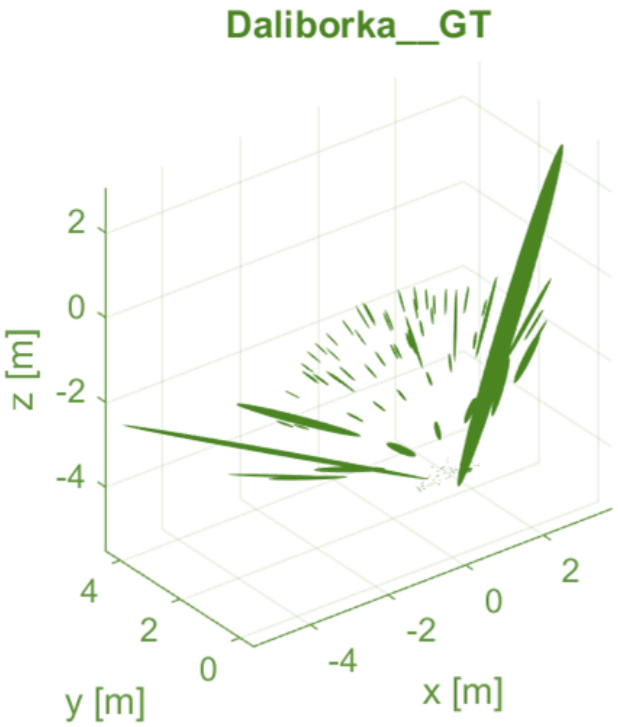
[LHUILLIER2006] - Uncertainty ellipsoids calculations for complex 3D reconstructions

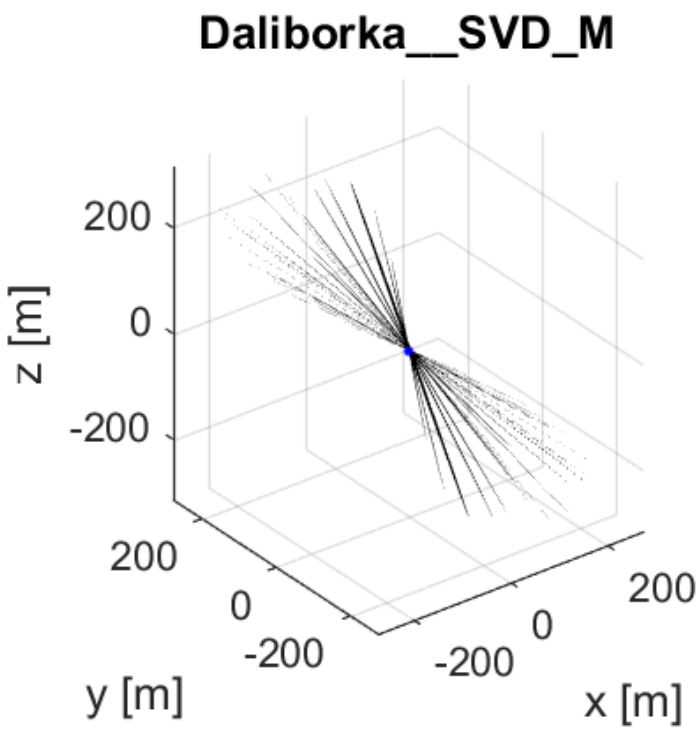
- Decomposition of Fisher information matrix $(J^T \Sigma_{\boldsymbol{u}}^{-1} J)^+ = \left(\begin{bmatrix} U_{\widetilde{N}} & W_{\widetilde{N}} \\ W_{\widetilde{N}}^T & V_{\widetilde{N}} \end{bmatrix} \right)^+$
- Numerically imprecise

Ground Truth vs. previous methods

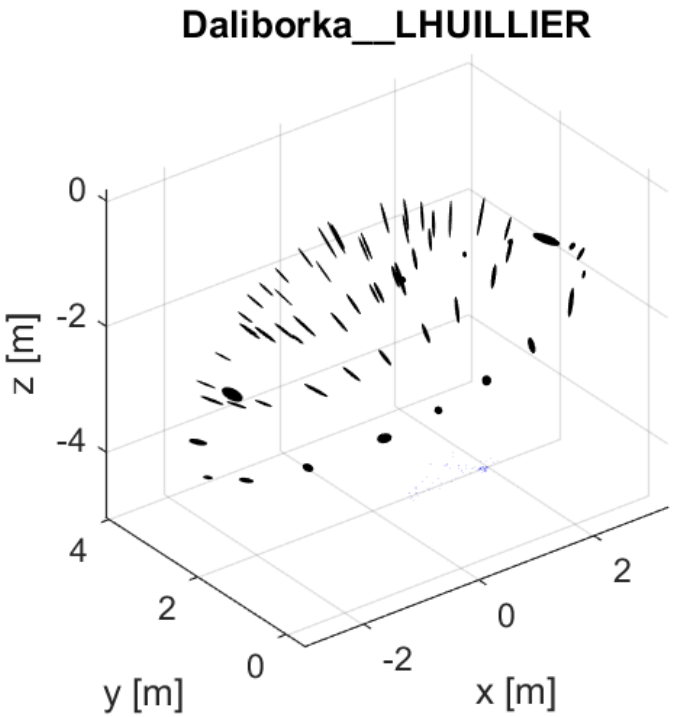
COMPARISON AGAINST GROUND TRUTH (64 cameras, 200 points in 3D)



100 significant digits



15 significant digits



15 significant digits

Our solution

REGULARISATION

- REMOVE LARGE RANGE VALUES IN JACOBIAN BY COLUMNS SCALING
- FIX THE SCENE SUCH A WAY TO MINIMIZE THE DEFFERENCE AGAINST MOORE-PENROSE PSEUDOINVERSION (FIX OF 3 MOST DISTANT POINTS)

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DECOMPOSITION

- LDU DECOMPOSITION TO SPEED UP THE PROPAGATION PROCESS

Our solution

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DECOMPOSITION

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APPROXIMATION OF THE INVERSION OF THE SCHUR COMPLEMENT MATRIX

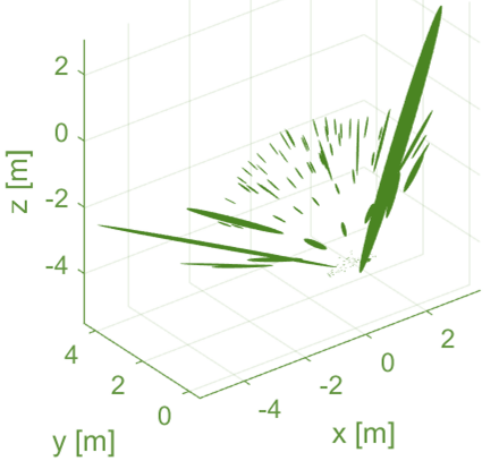
- IMPROVE NUMERICALL PRECISION AND ALLOW THE COMPUTATION FOR LARGE 3D SCENE

Results

- MORE PRECISE AND FASTER ALGORITHM FOR UNCERTAINTY PROPAGATION FROM FEATURE POINTS TO CAMERAS WHICH CAN BE USED IN PRACTISE

Daliborka__GT

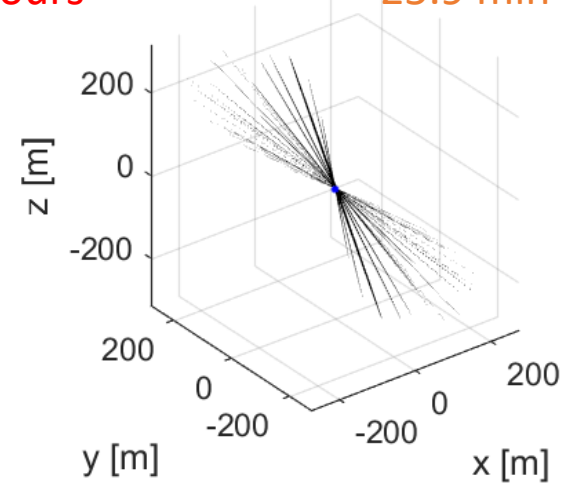
~22 hours



100 significant digits

Daliborka__SVD_M

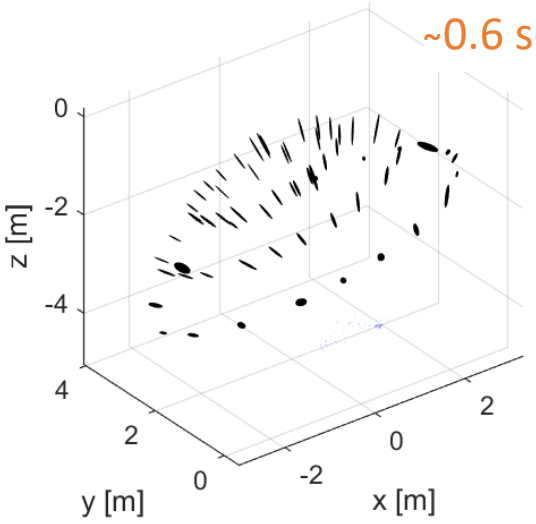
~25.9 min



15 significant digits

Daliborka__LHUILLIER

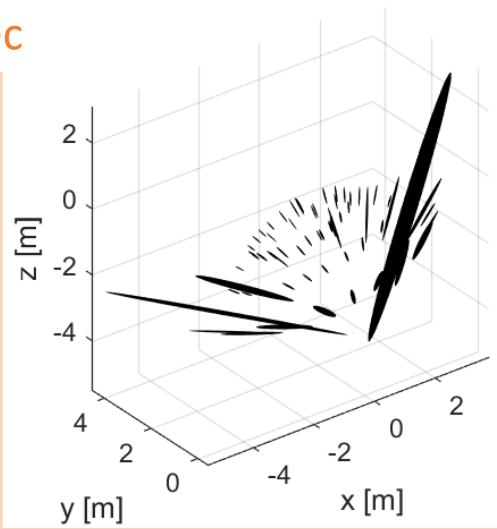
~0.6 sec



15 significant digits

Daliborka__INV_Z_SCALE_POINTS_FIX

~0.35 sec



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Thank you for attention

You are welcome to our poster!

The most relevant previous work

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[HARTLEY2003] - Hartley, Richard, and Andrew Zisserman. *Multiple view geometry in computer vision*. Cambridge university press, 2003.

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