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Camera Pose Estimation from Lines using Plücker Coordinates

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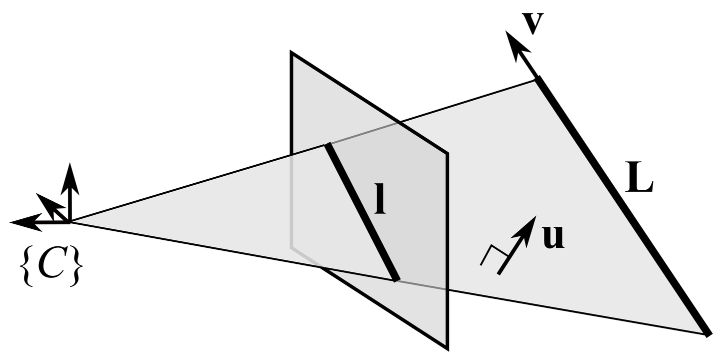
Abstract: Correspondences between 3D lines and their 2D images captured by a camera are often used to determine position and orientation of the camera in space. In this work, we propose a novel algebraic algorithm to estimate the camera pose. We parameterize 3D lines using Plücker coordinates that allow linear projection of the lines into the image. A line projection matrix is estimated using Linear Least Squares and the camera pose is then extracted from the matrix. An algebraic approach to handle mismatched line correspondences is also included. The proposed algorithm is an order of magnitude faster yet comparably accurate and robust to the state-of-the-art, it does not require initialization, and it yields only one solution. The described method requires at least 9 lines and it is particularly suitable for scenarios with 25 and more lines, as also shown in the results.

INTRODUCTION

Camera pose estimation is the determination of the position and orientation of a camera in 3D space. Correspondences between real world features and their counterparts in the image have to be known. The features can be e.g. points, lines, or other features. In the case of lines, the problem is called the **Perspective-n-Line** or the **PnL problem**.

3D lines can be represented using several parameterizations. **Plücker coordinates** are a complete but not minimal representation, and they allow a convenient linear projection of lines onto the image plane: $\mathbf{l} = \mathbf{P}\,\mathbf{L}$.



$$\mathbf{L} = \begin{pmatrix} \mathbf{u} \\ \mathbf{v} \end{pmatrix} = \begin{pmatrix} L_1 \\ L_2 \\ L_3 \\ L_4 \\ L_5 \\ L_6 \end{pmatrix},$$

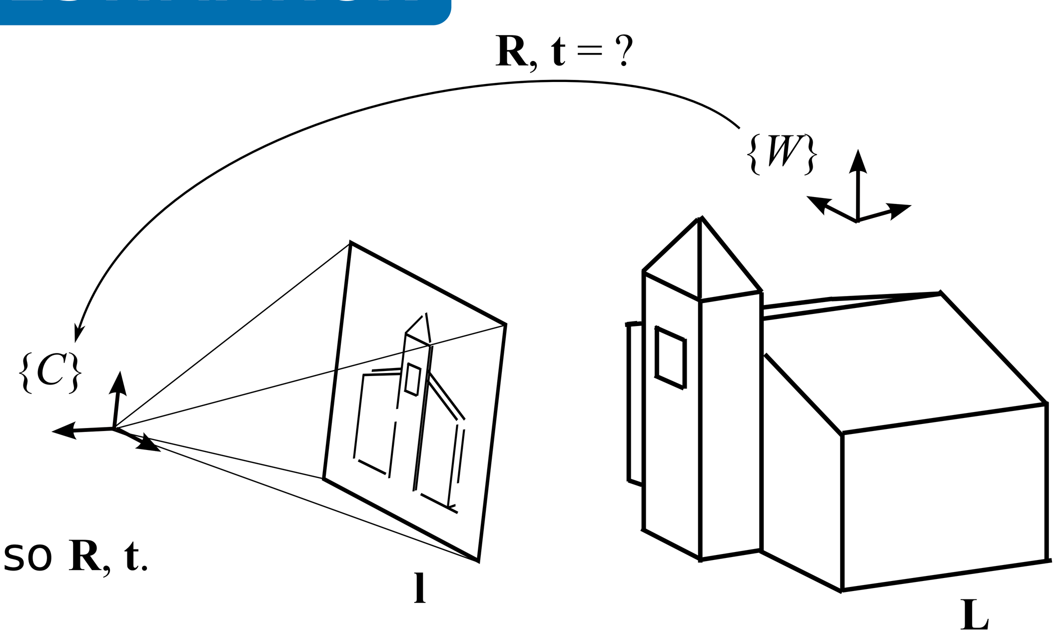
where $\mathbf{u}^\top \mathbf{v} = 0$.

METHOD OF POSE ESTIMATION

Projection of Plücker lines:

$$\mathbf{l} = \mathbf{P}\,\mathbf{L}\,,$$

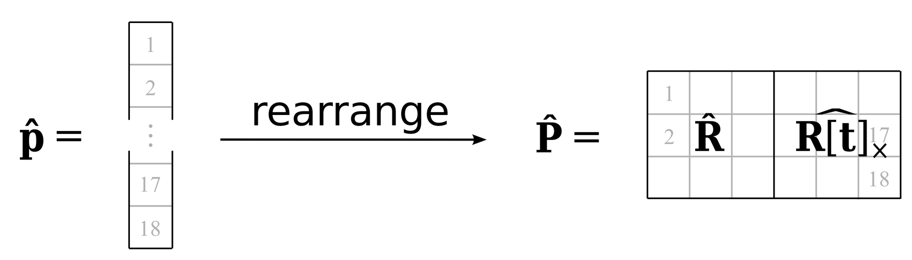
where $\mathbf{P} = (\,\mathbf{R} \quad \mathbf{R}[\mathbf{t}]_\times)$.



Goal: Estimate $\mathbf{P}$ and thus also $\mathbf{R}$, $\mathbf{t}$.

Algorithm:

1. Prenormalize $\mathbf{l}$, $\mathbf{L}$.
2. Direct Linear Transformation (DLT): Transform all equations into a homogeneous system: $\mathbf{M}\,\mathbf{p} = \mathbf{0}$ +noise → $\mathbf{M}\,\hat{\mathbf{p}} = \boldsymbol{\varepsilon}$
3. Solve for $\hat{\mathbf{p}}$ by minimizing $\boldsymbol{\varepsilon}$ in the least squarest sense, e.g. by SVD($\mathbf{M}$).



4. Extract $\mathbf{R}$, $\mathbf{t}$ from the right 3x3 submatrix of $\hat{\mathbf{P}}$ by a method for the decomposition of an essential matrix.

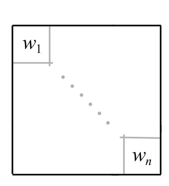
REJECTION OF MISMATCHED LINES

RANSAC is commonly used to identify and remove mismatches. However, it is unsuitable for our method, because it works with the minimal number of 9 line correspondences. This would lead to increased number of iterations. Therefore, we use an alternative scheme called **Algebraic Outlier Rejection** (AOR) [3]. It is an iterative approach integrated directly into the pose estimation procedure in form of Iteratively Reweighted Least Squares. Wrong correspondences are identified as outlying based on the residual $\boldsymbol{\varepsilon}$ and are assigned zero weights for the next iteration.

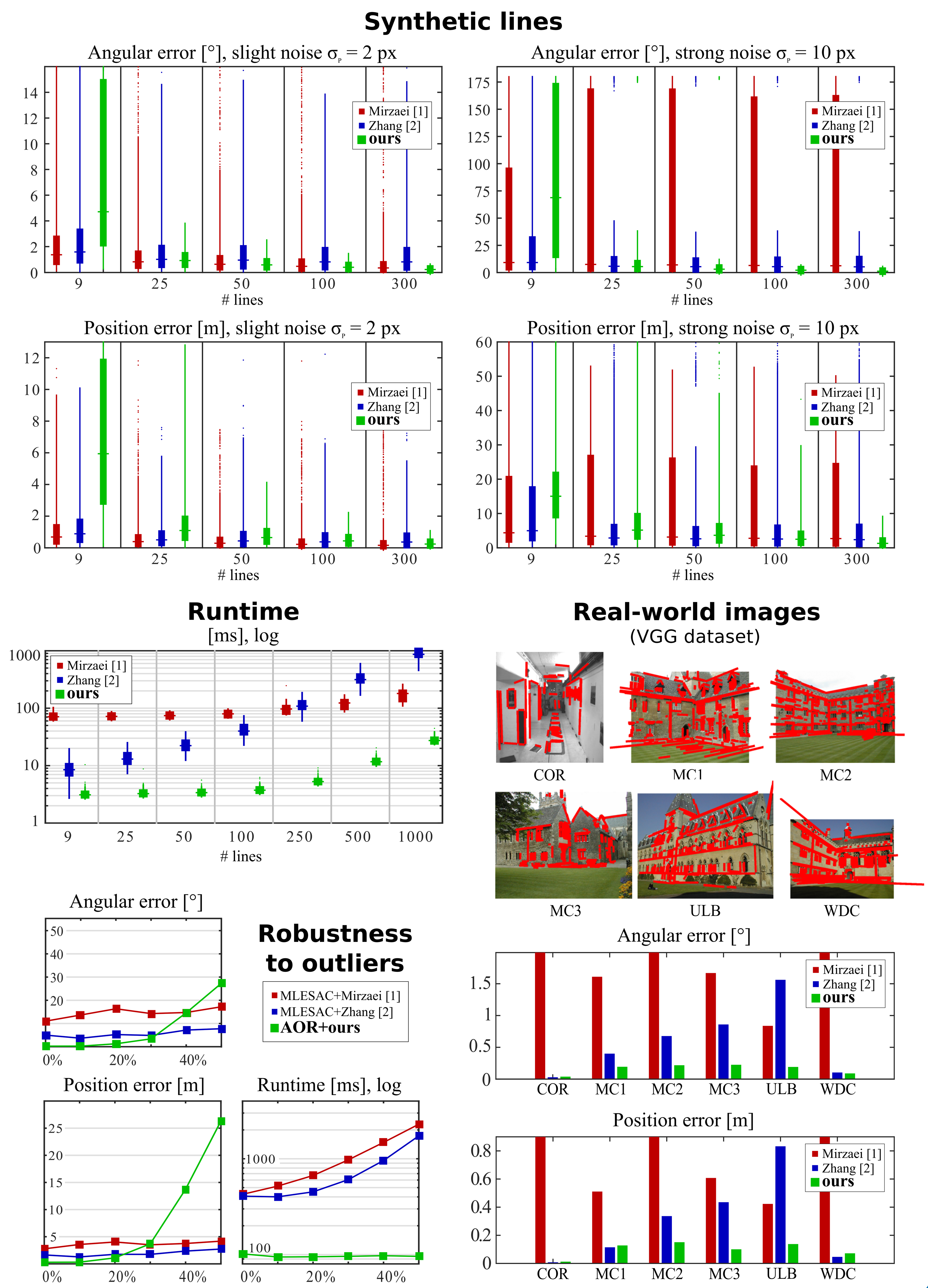
$$\mathbf{W}_{(t)}\,\mathbf{M}\,\hat{\mathbf{p}}_{(t)} = \boldsymbol{\varepsilon}_{(t)}$$

iterate (t)

$\mathbf{W}_{(t)} =$



EXPERIMENTAL RESULTS



CONCLUSIONS

We developed a novel algebraic algorithm for camera pose estimation from line correspondences, which is particularly suitable for large scale and noisy scenarios.

- ⊕ Super fast (an order of magnitude faster than SotA).
- ⊕ Comparably accurate and robust to SotA.
- ⊕ Requires no initialization.
- ⊕ Yields a unique solution.
- ⊖ 9 or more lines required.
- ⊖ 25 or more lines needed for robust performance.

Matlab code available for download.

References

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