Multiview Absolute Pose Using 3D - 2D Perspective Line Correspondences and Vertical Direction

Nora Horanyi, Zoltan Kato
Research Group on Visual Computation, University of Szeged
(http://www.inf.u-szeged.hu/rvgc/)

Problem statement

Goal: absolute pose estimation, to determine the position and orientation of a multiview camera system with respect to a 3D world coordinate frame.

Contribution: We propose two methods to compute absolute pose from 3D - 2D perspective line pairs. Both can be used as a minimal solver as well as least squares solver without reformulation.

Assumption:
- Vertical direction is available.
- 3D lines are represented as \( L = (V, X) \).
- Projection of line \( L \) is given as \( l = ((x, y)) \).
- \( r \) is the unit normal to the projection plane.

Efficient solutions

How to get rid of the trigonometric functions in \( R(\alpha) \)?

I. Solution: Linear solution (NPnPUpL)

Let \( c = \cos(\alpha) \) and \( s = \sin(\alpha) \) be separate unknowns:

\[ R(\alpha) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & c & -s \\ 0 & s & c \end{bmatrix} \]

Substitution into (1) (2) yields a simple linear system of equations.

II. Solution: Cubic polynomial solution (NPnPUpC)

Substituting \( q = \tan(\alpha) \), gives us the following form of \( R(\alpha) \):

\[ R(\alpha) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\alpha) & -\sin(\alpha) \\ 0 & \sin(\alpha) & \cos(\alpha) \end{bmatrix} \]

Substitute \( q = \tan(\alpha) \) into (1) and solve it in the least squares sense. Solved for \( 2 \), \( 3 \), \( 4 \), and \( 5 \). Its derivative should vanish:

\[ \alpha = \frac{4a^2 + 4b^2 + 4c^2}{16 + 8ab + 8bc + 8ca} \]

The 3 roots are the possible solutions for \( q \).

Method

- Linear solver has good accuracy for reasonable computing time.
- Distributions of the model has been ignored (\( 0 < \alpha < \pi \)).
- Solution can be far from a rigid body transformation for noisy input data.

Advantages

- Trigonometric constraint on \( \alpha \) is explicitly taken into account.
- Increased robustness under noisy observations.

Disadvantages

- The estimation of \( n \) and \( d \) is decoupled, no error in \( n \) is directly propagated into the linear system of \( t \).
- Computational complexity is slightly higher than the pure linear solver.

Synthetic data

Various benchmark datasets of 3D-2D line pairs for robustness tests we add random noise to these datasets in the following way:

- 2D lines are corrupted with additive random noise on one endpoint of the line and the direction vector of the line (5% and 8%).
- This corresponds to a quite high noise rate: \([-20, -2] \) pixels for the 5% case and \([-30, -30] \) pixels for the 8% case.
- We evaluate our methods as least squares solver as well as minimal solver.
- We need 3 line pairs in the minimal case.
- Implementation of the methods in MATLAB.

Quantitative evaluation

Comparison of the rotational errors for stereo camera pairs w.r.t. the baseline.

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Real datasets

Kolozsremeta dataset NPnPUpL NPnPUpC UPnP

- Rotation error (deg): 0.0166 0.0175 0.0498
- Translation error: 0.0402 0.0319 0.0119

Conclusion

- We proposed two direct solutions which can be used as minimal solver (e.g. within RANSAC) as well as general least squares solver without reformulation.
- Methods work for single- and multi-view perspective camera systems.
- Linear solver is computationally more efficient but it is more sensitive to noise and low number of correspondences.
- Cubic solver is much more robust at the price of slightly increased CPU time.
- The proposed method have been evaluated on synthetic and real datasets. Comparative tests confirm state of the art performance both in terms of quality and computing time.

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