Direct vs. Feature-Based Methods for Structure and Motion Estimation

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1. P.H.S. Torr and A. Zisserman: Feature Based Methods for Structure and Motion Estimation
2. M. Irani and P. Anandan: All About Direct Methods
Part I: Feature Based Methods

Structure and motion recovery should proceed by first extracting features, and then using these features to compute the image matching relations. It should not proceed by simultaneously estimating motion and dense pixel correspondences.
Motivating Example: Planar Homography

\[ x' = Hx \]

\(x\) and \(x'\) contains homogeneous coordinates, \(H\) is 3x3.
Objective: Compute the 2D homography between two images.

Algorithm

1. **Features:** Compute interest point features in each image to sub pixel accuracy (e.g. Harris corners [11]).
2. **Putative correspondences:** Compute a set of interest point matches based on proximity and similarity of their intensity neighbourhood.
3. **RANSAC robust estimation:** Repeat for $N$ samples
   (a) Select a random sample of 4 correspondences and compute the homography $H$.
   (b) Calculate a geometric image distance error for each putative correspondence.
   (c) Compute the number of inliers consistent with $H$ by the number of correspondences for which the distance error is less than a threshold. Choose the $H$ with the largest number of inliers.
4. **Optimal estimation:** re-estimate $H$ from all correspondences classified as inliers, by minimizing the maximum likelihood cost function (1) using a suitable numerical minimizer (e.g. the Levenberg-Marquardt algorithm [23]).
5. **Guided matching:** Further interest point correspondences are now determined using the estimated $H$ to define a search region about the transferred point position.

The last two steps can be iterated until the number of correspondences is stable.

**Table 1.** The main steps in the algorithm to automatically estimate a homography between two images using RANSAC and features. Further details are given in [30].
Advantages of Feature Based Methods

• Can handle large disparities
• Invariance
  – Photometric
  – Geometric
• Optimal estimation
• Computational efficiency and convergence
  – Bootstrap dense depth from sparse correspondences
Part II: Direct Methods
The Brightness Constraint

\[ J(x, y) = I(x + u(x, y), y + v(x, y)) \]

\[ I_x u + I_y v + I_t = 0 \]

Differential motion assumption

[Horn & Schunck 1981]
Motivating Example: Affine Motion Model

\[ u(x, y) = a_1 + a_2 x + a_3 y \]
\[ v(x, y) = a_4 + a_5 x + a_6 y \]

\[ I_x (a_1 + a_2 x + a_3 y) + I_y (a_4 + a_5 x + a_6 y) + I_t = 0 \]

• solve using least squares, e.g. over entire image
• all pixels participate, not just “rank 2” neighborhoods
• large disparities handled using multiresolution (pyramid)
Panoramic mosaic
Video enhancement

(a) (b)
Dominant motion selection and outlier rejection
Properties of Direct Methods

• Sub-Pixel Accuracy
• Locking Property and Outlier Rejection
• Can be applied to several motion models
  – Affine
  – Planar Surface
  – Plane+parallax
• Can be extended to handle non-brightness based similarity measures