Structure-from-Motion Algorithm

Bundle Adjustment
Structure from motion
Photo Tourism overview

Input photographs

Scene reconstruction

Photo Explorer

Relative camera positions and orientations
Point cloud
Sparse correspondence
Scene reconstruction

- Automatically estimate
  - position, orientation, and focal length of cameras
  - 3D positions of feature points

Feature detection → Pairwise feature matching → Correspondence estimation → Incremental structure from motion
Feature detection

Detect features using SIFT [Lowe, IJCV 2004]
Feature detection

- Detect features using SIFT [Lowe, IJCV 2004]
Pairwise feature matching

• Match features between each pair of images
Feature matching

Refine matching using RANSAC [Fischler & Bolles 1987] to estimate fundamental matrices between pairs
Structure from motion

minimize $f(R, T, P)$

$R_1, t_1$

$R_2, t_2$

$R_3, t_3$
Minimize the re-projection error

$$E(M, X) = \sum_{i=1}^{m} \sum_{j=1}^{n} D(x_{ij}, M_i X_{ij})^2$$

Estimate: $M = \text{Projection matrix, } X = \text{3D points}$
Levenberg–Marquardt algorithm

Minimize

\[ S(\beta) = \sum_{i=1}^{m} [y_i - f(x_i, \beta)]^2 \]

\[ f(x_i, \beta + \delta) \approx f(x_i, \beta) + J_i \delta \]

Where, \[ J_i = \frac{\partial f(x_i, \beta)}{\partial \beta} \]

At its minimum, the sum of squares, \( S(\beta) \), the gradient of \( S \) with respect to \( \delta \) will be zero. The above first-order approximation of gives

\[ S(\beta + \delta) \approx \sum_{i=1}^{m} (y_i - f(x_i, \beta) - J_i \delta)^2. \]

In the vector notation,

\[ S(\beta + \delta) \approx \|y - f(\beta) - J \delta\|^2. \]

Taking the derivative with respect to \( \delta \) and setting the result to zero gives,

\[ (J^T J) \delta = J^T [y - f(\beta)] \]
Incremental structure from motion
Incremental structure from motion
3D reconstruction
Demo
• Advantages

Handle large number of views
Handle missing data

• Limitations

Large minimization problem (parameters grow with number of views) – Takes lot of time
requires good initial condition
REFERENCES:


Youtube Link: [http://www.youtube.com/watch?v=9M4KWgRGNa0](http://www.youtube.com/watch?v=9M4KWgRGNa0)

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