GEA Optimization for Live Structureless Motion Estimation[1]

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Problem statement:

Map optimization prevents divergence, corrects loop closing errors and obtains optimal reconstructions. But it can be a performance bottleneck in real-time systems, limiting scalability.

Proposal:

GEA[4] optimizes only the set of camera poses in the map, instead of error correction methods such as SBA, which must also include the structure. The former optimization is significantly faster than state of the art SBA implementations.

A simplification of the GEA cost error function significantly speeds up the Levenberg-Marquardt optimization, without compromising error reduction.

1. GEA cost error.

GEA optimizes camera poses in the reconstruction by enforcing pair-wise epipolar constraints in the following cost error:

$$C_e = \sum_{i,j} \sum_{p[i,j]} \left(x_i^{(p)T} E_{ij}\, x_j^{(p)} \right)^2 = \sum_{i \neq j} \|M_{ij} e_{ij}\|^2$$

Where:

$\mathbf{E_{ij}}$ → Essential matrix for views *i-j*, parametrized with camera poses.

$\boldsymbol{x^{(p)}}$ → *2D feature tracking for 3D point* ***p****.*

$\mathbf{e_{ij}}$ → Vector containing the essential matrix elements.

$\boldsymbol{M_{ij}}$ → *LDT matrix for feature point matchings between key-frames i-j.*

2. Efficient cost error simplification.

Each term in C_e enforces the epipolar constraint defined between a pair of key-frames with point correspondences.

Approach*: discard terms in the cost error which are less relevant for the camera poses network structure; two algorithm parameters, 's' and 'k':*

(1) Do not discard terms corresponding to pairs of views which are closer than 's' key-frames in the video sequence.

(2) Keep 'k' terms for each key-frame, involving the largest number of point correspondences.

3. GEA integration in a real-time tracking system.

Camera tracking and loop-closing detection:

Incremental reconstruction for short-term camera tracking: optimization of most recent key-frames with GEA or SBA. Reduced 3D reconstruction used to resect new camera poses. 2D point tracking (KLT) and/or matching (FAST+BRIEF) for short-term correspondences.

Loop closing detection: normalized scaled SSD for fast detection of matching images, BRIEF features for feature point matching.

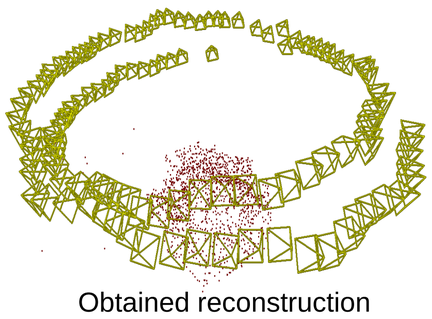
Efficient loop closing error correction: GEA optimization with simplified cost error is applied on loop closing detection in a parallel thread. Only a reduced set of 3D feature locations (required to resect new camera poses) is updated.

4. Results.

4.1. GEA loop closing correction compared with sSBA:

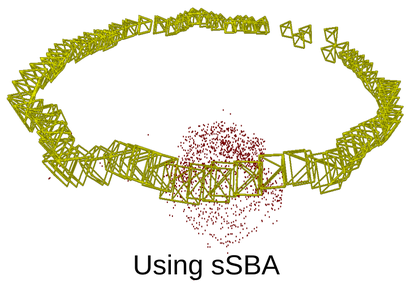
Incremental reconstruction:

Input video sequence

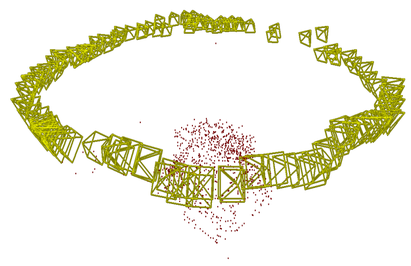


Obtained reconstruction

Loop-closing error correction:

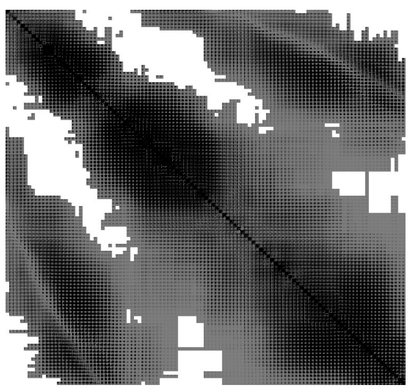


Using sSBA

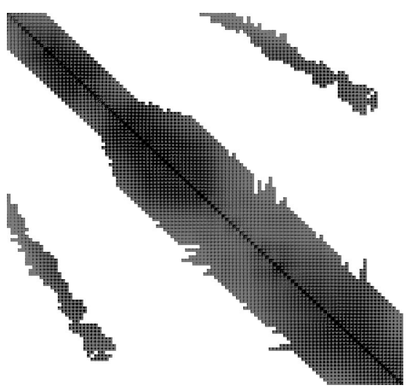


Using GEA

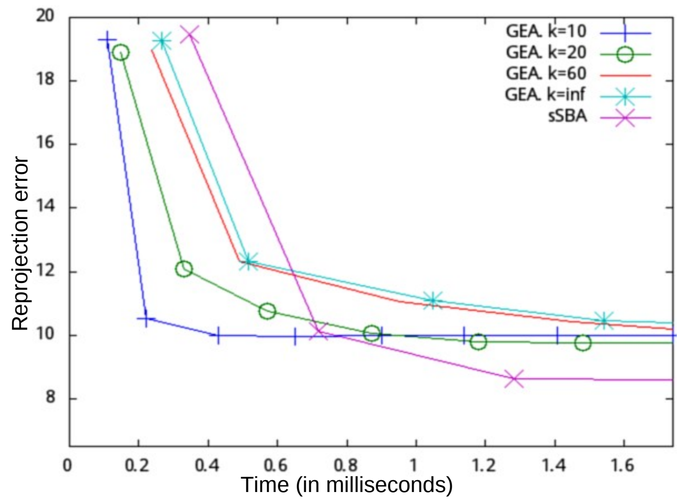
4.2. Error reduction performance: sparsity of the second-level Hessian matrix is increased without decreasing error optimization speed.



K = 60, s = 10



K = 10, s = 10



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1. http://perception.inf.um.es/gea
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4. *Reduced Epipolar Cost for Accelerated Incremental SfM.* A. L. Rodríguez, P. E. López-De-Teruel, A. Ruiz. In Proc. Of CVPR 2011.