IMPROVED 3D SPARSE MAPS FOR SFM WITH LOW-COST OMNIDIRECTIONAL ROBOTS

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Issue: Coping with noisy imagery and small baselines for Structure from Motion (SfM) on low-budget omnidirectional platforms

Approach: Noise-tolerant (σ~10) feature tracking method that facilities the effective implementation of 3D reconstruction on low-cost omnidirectional robots, not achieved before [1]
(1) Bilateral filtering: efficient inexpensive method feature preserving noise reduction.
(2) Feature extraction: and k-d tree based lookup for pairwise image matching. Matches selected according to:
(i) Lowe filter, (ii) Selection based on $L_2$ distance between features matched, and (iii) one-to-one feature matching enforced.

(3) RANSAC and algebraic error minimisation method
(4) Feature tracking: optimise the scarcity of the selected matches by efficiently managing the bundles created by a 3D point X and its views. Our system allows: a) Direct access from X to any of its views and vice versa, b) Automatic addition of new features to a bundle, and c) efficient merging of bundles
   - Two filters handle the management of bundles: $f_1$: Only one view of X per frame is allowed.
   - $f_2$: Finds 3D points which are actually the same.

(5) Joint Pose and structure estimation: bundle-enabled resection and Triangulation
(6) Refinement with local Bundle Adjustment (BA) over last 10 frames. Global BA is run in the background.
(7) Post-process: Matching and Triangulation processes is re-run, no selection filters, thresholds relaxed. Number of 3D points are doubled.
(8) Final scene recovery: The resulting point cloud is filtered by statistical techniques, over which a smooth surface is estimated by Moving Least Square surface reconstruction and Poisson method.

Results

<table>
<thead>
<tr>
<th></th>
<th>3D Points</th>
<th>Projections</th>
<th>Reproj. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>SfM with Feature tracking</td>
<td>24,393</td>
<td>100,753</td>
<td>1.53</td>
</tr>
<tr>
<td>PhotoScan</td>
<td>8,783</td>
<td>38,534</td>
<td>44.06</td>
</tr>
<tr>
<td>VisualSfM</td>
<td>4,288</td>
<td>35,789</td>
<td>4.51</td>
</tr>
</tbody>
</table>

Comparison on the laboratory sequence with state-of-the-art softwares PhotoScan and VisualSfM.

Summary: Noise-resilient SFM robust to small baselines configurations with a novel feature tracking method that optimises the tracks given by scarce match population [2], typical of low quality images delivered by low-cost omnidirectional robots.