# Weighted Local Bundle Adjustment and Application to Odometry and Visual SLAM Fusion

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The aim of Monocular Visual SLAM is to determine the camera localisation at each image and a sparse representation of the environment. There are two main approaches: kalman based ([1]) and bundle adjustment based ([4] and [3]).

In monocular SLAM, the scene structure and camera motion are theoretically reconstructed up to an unknown scale factor. Unfortunately, experiments show that the scale factor drifts during long trajectories. This problem is a major limitation in monocular visual SLAM. One possible solution is to rely on another sensor to estimate the scale but it involves the fusion of information from monocular visual and the other sensor.In automotive scenario, odometer seems to be the most adapted sensor.

Contrary to kalman based approach, Local Bundle Adjustment(**LBA**) does not provided uncertainty. This issue makes the fusion no optimal. Recently, we proposed in [2] a solution of this problem by using Weighted Local Bundle Adjustment (**W-LBA**) to propagate uncertainty in real time.

In this paper, we propose different applications of W-LBA. First, we show that W-LBA can also be used for geometry optimisation and propose another weighting scheme in order to improve efficiency. Next, we use the W-LBA to fuse visual SLAM with odometer measurements.

**Bundle Adjustment**  Bundle adjustment [5] is a well known iterative method designed to solve non-linear least square problems in Structure-from-Motion. It refines simultaneously the scene (3D points cloud) and the camera poses by minimising the reprojection errors. Unfortunately, this method is very time consuming. To overcome this limitation, iterative methods, called Local Bundle Adjustment, were introduced.

Local Bundle Adjustment is a Bundle Adjustment on a sliding window. In this windows, only the newest cameras are optimised, the old cameras are fixed because we consider that the old one are already well optimised. They are only used as constraint to optimise the 3D points cloud. In this way the geometry of long sequence can be iteratively refined in real-time.

The weighted LBA is a LBA but the old cameras are now allowed to move but less than new one. The constraint on old poses localisation is build according to the localisation at the previous step and weighted by a covariance matrix. This weighting acts on how the W-LBA takes into account of the old estimated poses.

In previous work[2], we propagate uncertainty of the old poses through iterations and call it global covariance. In this paper, we propose to use an other weighting scheme. Instead of using the global covariance that has the property to increase during time and is similar to one computed with global bundle adjustment, we use a local one that does not grow and represents uncertainty of camera respectively to the oldest camera in the local bundle.

In [2], there is no performance evaluation of the W-LBA bundle, we only give the mathematical formulation and derive the propagation of covariance. In this paper, we make a comparison between LBA, W-LBA with global uncertainty and W-LBA with local uncertainty.

We observe that the W-LBA with global uncertainty gives quite similar results than LBA. However, the W-LBA with local uncertainty is more appropriate and gives more accurate results than W-LBA with global uncertainty. It is more accurate in position and has less scale propagation error.

**Odometer Integration**  In this paper, we propose to use the W-LBA with local covariance to integrate odometer constraints in the optimisation process. We use W-LBA to integrate constraint because a part of the estimated cameras (old cameras) are constrained by their previous estimation. Using this property, this LBA can be used to impose constraint
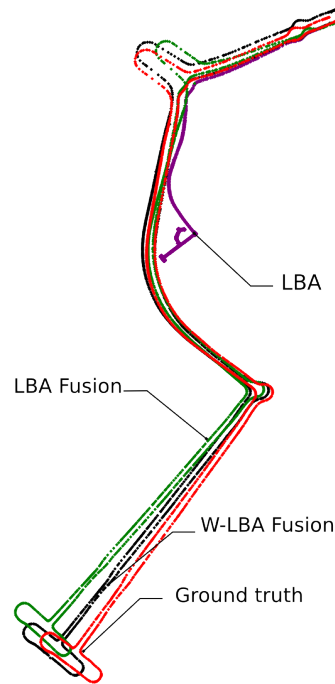


Figure 1: Top view of the reconstruction of the different methods of fusion with odometer (LBA fusion and W-LBA fusion) and the ground truth of a 4km sequence in real urban area.

on old cameras. In our case, we will add constraints coming from the odometer measurement by correcting the old poses.

In figure 1, we observe that the scale factor drift is important at the end of the sequence with LBA. Thus fusion is a necessity to provide a correct trajectory reconstruction. Indeed, the two fusion methods, contrary to the standard monocular SLAM (LBA), achieved to reconstruct the 4 km sequences with less that 40m error. Our method is more compliant with ground truth scale and has a lower error in position with a mean error of only 18 meters.

**Conclusion**  In this paper, we highlight the use of Weighted Local Bundle Adjustment with local covariance to increase the accuracy of reconstruction and reduce the drift of scale factor. We demonstrate and prove with experiments, that W-LBA used with local covariance can be used for data fusion. The fusion with odometer data allows to reduce the scale factor drift due to lack of constraint in the monocular visual SLAM.

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