PARALLELISING BUNDLE ADJUSTMENT

Salas-Moreno R. - Imperial College London
r.salas-moreno10@imperial.ac.uk

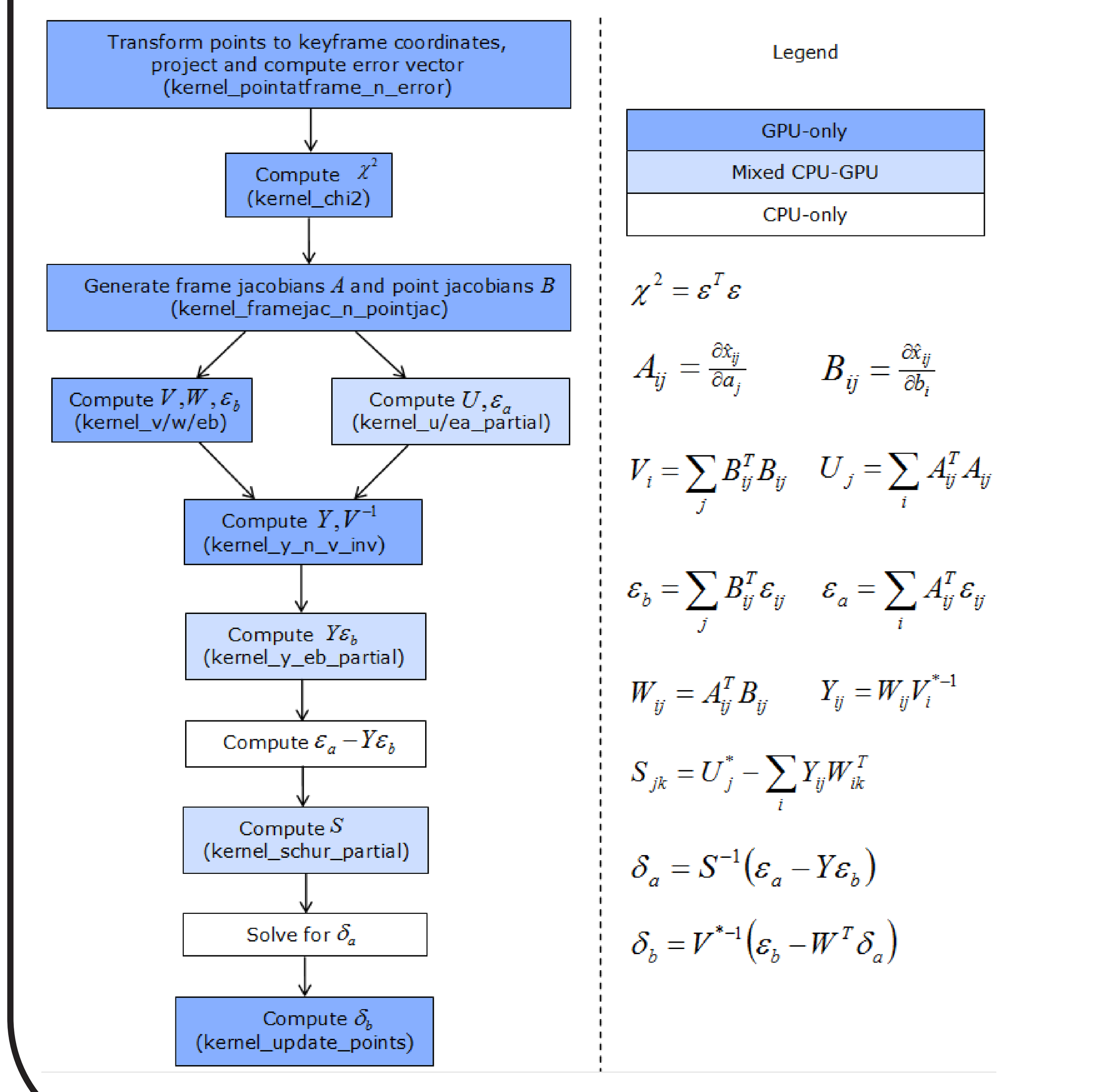
ICVSS 2011
Sicily ~ 11-16 July
International Computer Vision Summer School

Abstract

Bundle Adjustment (BA) is one of the final steps in feature-based 3D reconstruction with a moving camera. By optimising the estimated set of point and camera parameters, it helps to increase trajectory accuracy and reduce error-buildup.

Aiming to optimise dense reconstruction results in real-time [1], we identified sub-steps suitable for parallel computations and implemented a hybrid GPU/CPU solution with speed-ups of up to 10 times compared to a recent CPU-only version [2].

GPU/CPU steps

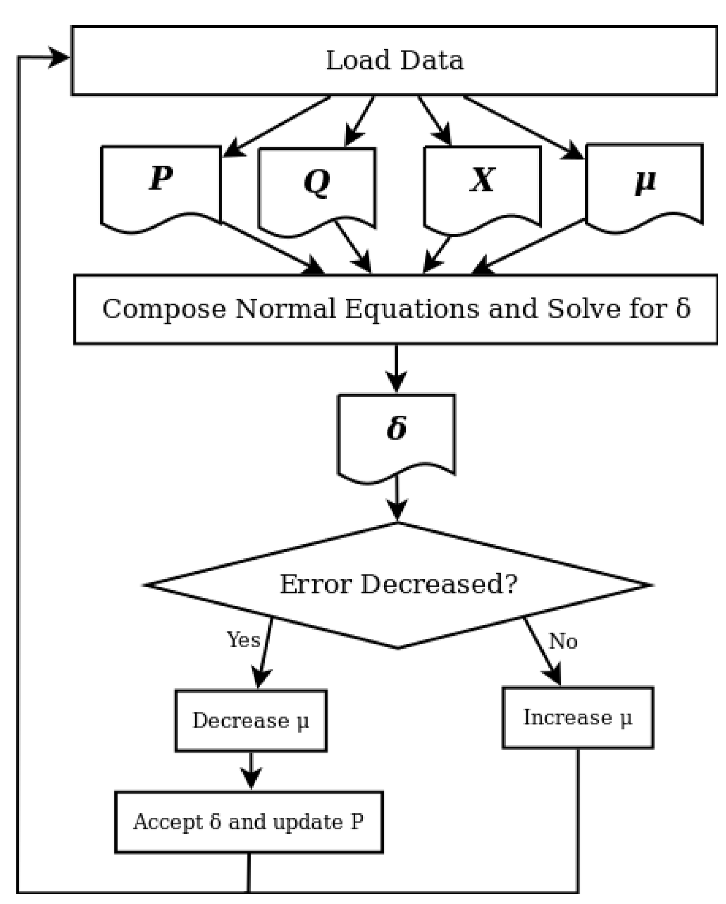


Difficulties

- GPU version suitable when data size is above 1K items due to host-device data transfer costs.
- Double precision speed is typically half of single precision on GPUs.
- Large data structures (e.g. 6x6 matrix) complicates opportunities for memory coalescing.
- Performing reductions from a set of large matrices saturates GPU shared-memory and registers severely limiting occupancy.

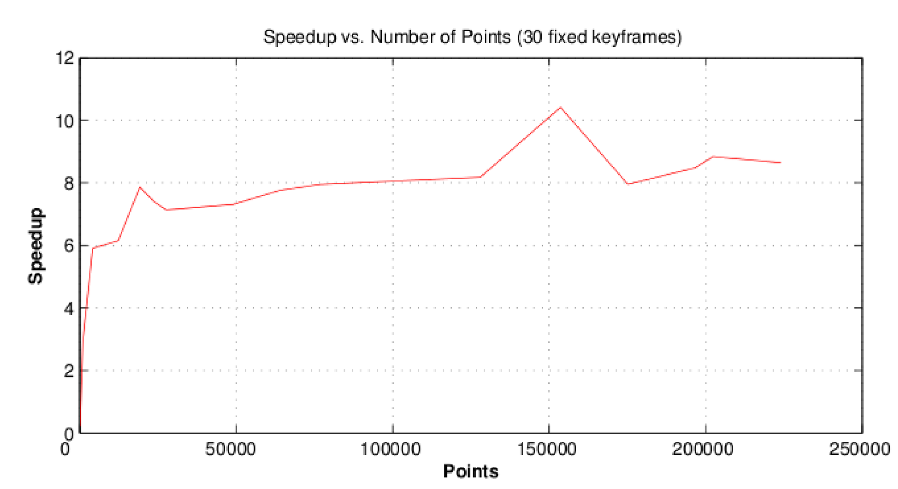
Levenberg-Marquardt BA

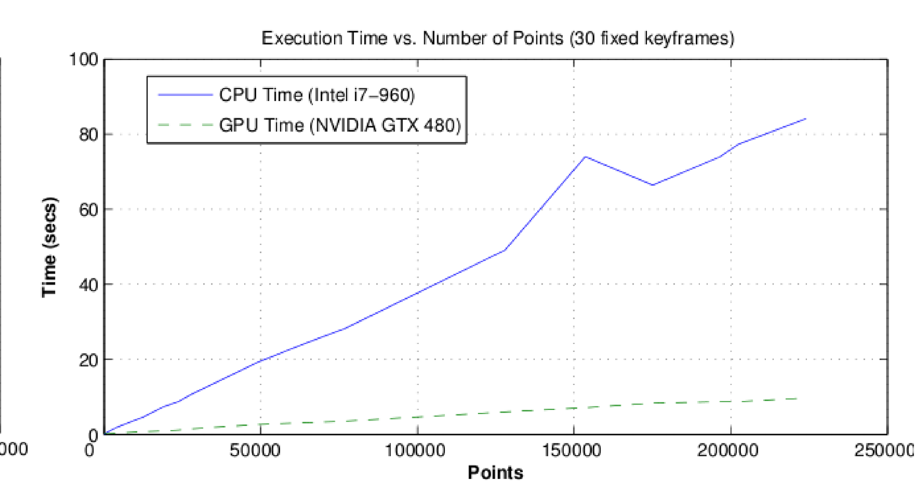
Each iteration consists of [3]:

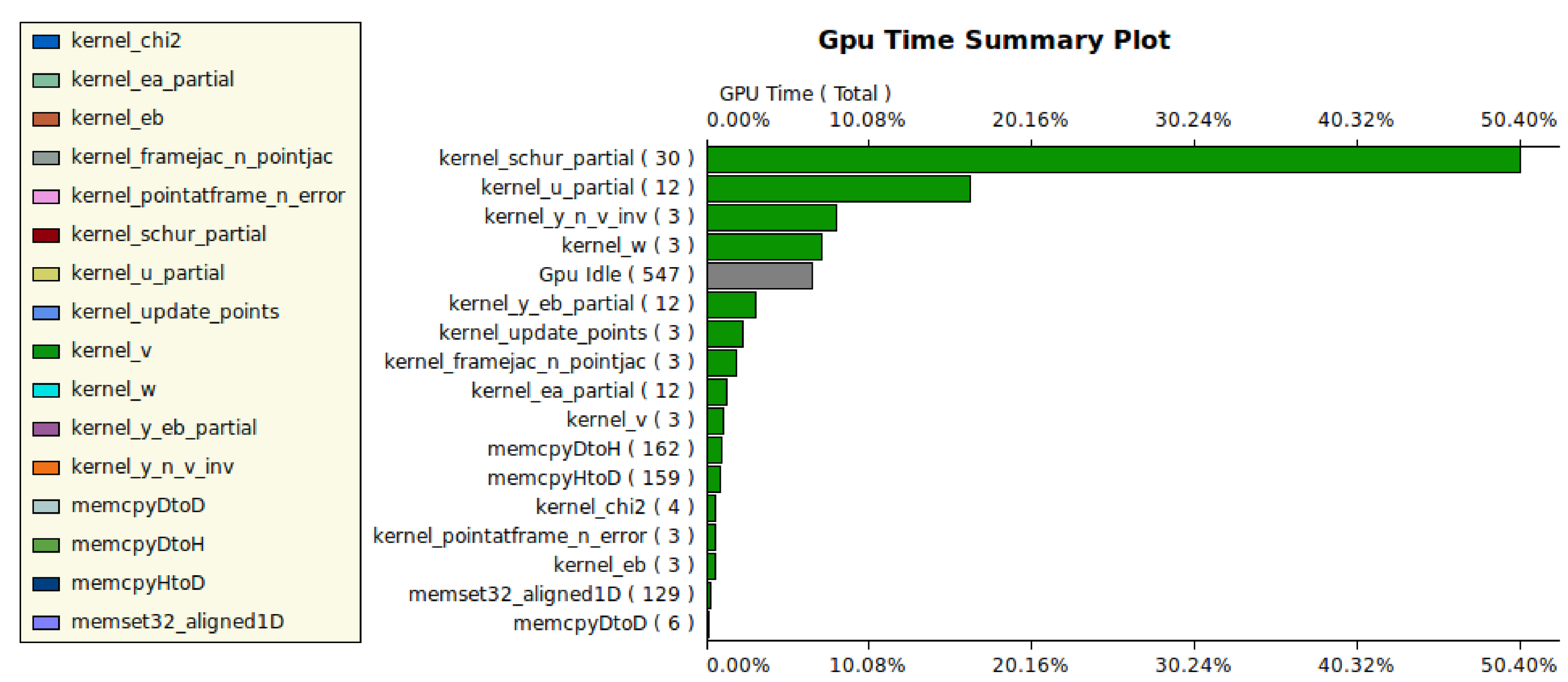


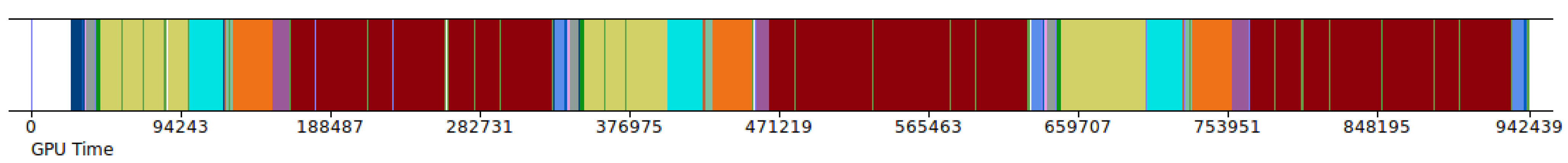
Where:
$\boldsymbol{P} = (\boldsymbol{a}_1^T, ..., \boldsymbol{a}_m^T, ..., \boldsymbol{b}_1^T, ..., \boldsymbol{b}_n^T)^T$ is the parameter vector to optimise for m keyframes and n points,
$\boldsymbol{a}_j$ is the j^th camera parameters,
$\boldsymbol{b}_i$ is the i^th 3D point position,
$\boldsymbol{Q}(a_j, b_i)$ projects $\boldsymbol{b}_i$ into $\boldsymbol{a}_j$,
$\boldsymbol{X} = (\boldsymbol{x}_{11}^T, ..., \boldsymbol{x}_{1m}^T, ..., \boldsymbol{x}_{n1}^T, ..., \boldsymbol{x}_{nm}^T)^T$ is the 2D point measurements across all keyframes,
$\boldsymbol{\mu}$ is the damping term guaranteeing a reduction in the error at each iteration, $\boldsymbol{\delta}$ is the solution to update $\boldsymbol{P}$ at the current iteration.

Results for 3 Iterations

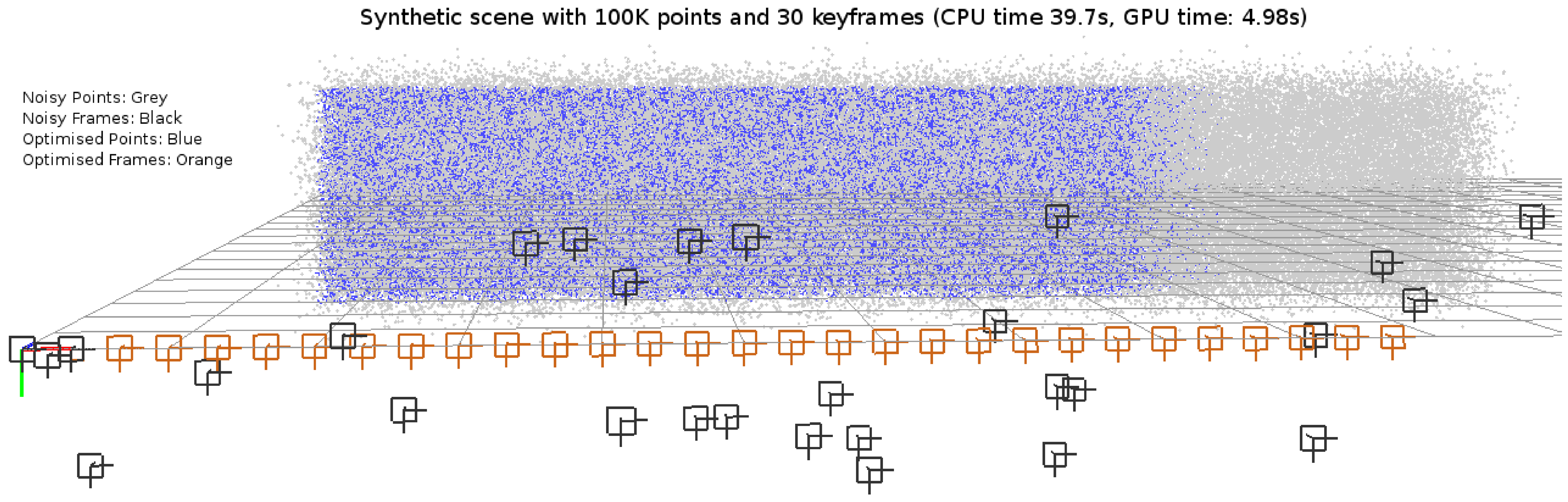








Synthetic scene with 100K points and 30 keyframes (CPU time 39.7s, GPU time: 4.98s)



Acknowledgements

Special thanks Dr. Andrew Davison and Hauke Strasdat for their guidance and cooperation on this work and AMD for sponsoring this research.

References

[1] Newcombe R. and Davison A. J., Live Dense Reconstruction with a Single Moving Camera, in *Computer Vision and Pattern Recognition (CVPR)*, 2010.

[2] Strasdat H., Montiel J. M. M., and Davison A. J., Scale drift-aware large scale monocular SLAM, in *Proceedings of Robotics: Science and Systems (RSS)*, 2010.

[3] Lourakis M. I. A. and Argyros A. A., SBA: A Software Package for Generic Sparse Bundle Adjustment, in *ACM Transactions on Mathematical Software*, 2009.