GPGM-SLAM: Towards a Robust SLAM System for Unstructured Planetary Environments with Gaussian Process Gradient Maps

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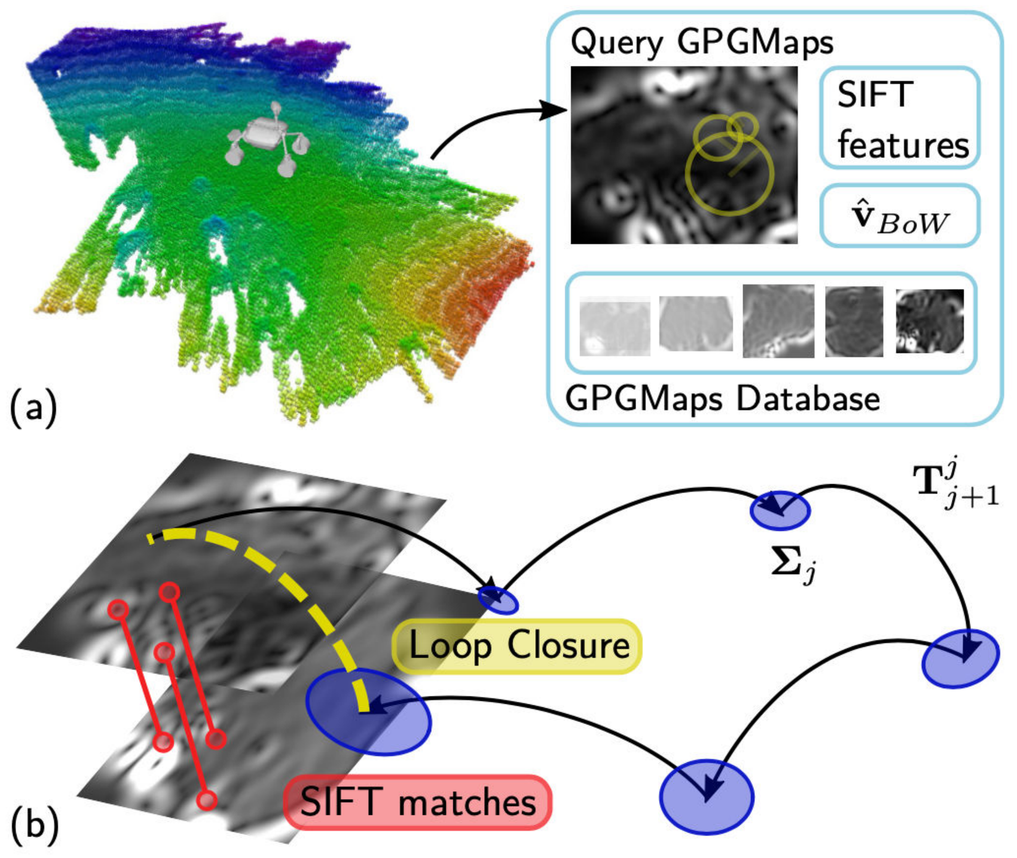
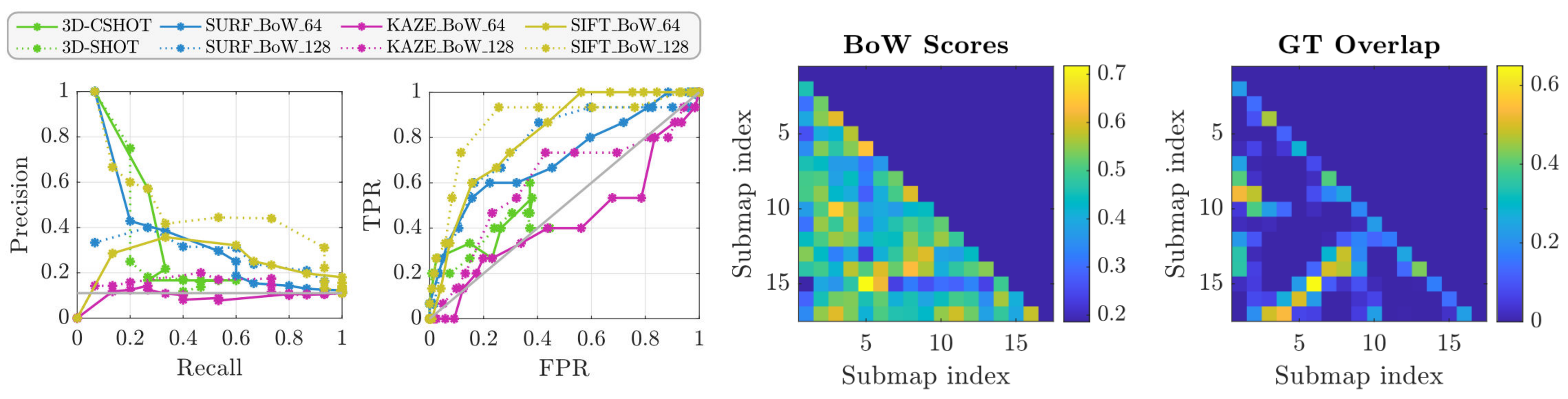
GPGM-SLAM

- Submap-based SLAM system targeted at mobile rovers with stereo cameras [1]
- Tackles the problem of establishing loop closures using Gaussian Process Gradient Maps (GPGMaps) [3]
- GPGM: gradient of submap elevation computed using Gaussian Processes (GP) and SKI (Structured Kernel Interpolation) [2]
- Similarity score between GPGMaps computed online in a Bag-of-Words (BoW) framework using image features computed on gradients
- Pose graph links origins of submaps with Visual-inertial Odometry constraints and validated loop closures



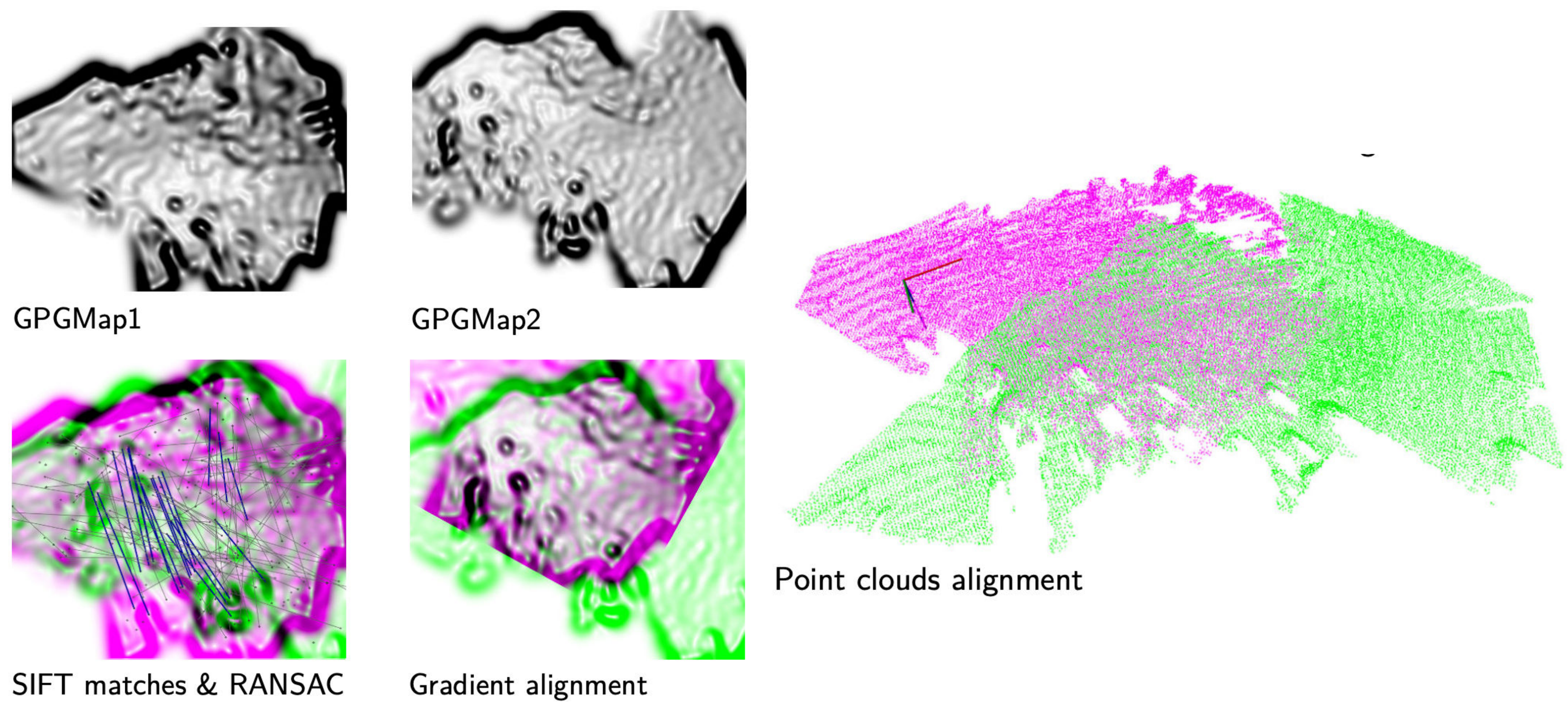
Loop Closure detection using Bag-of-Words on GPGMaps

- Evaluation of SIFT, SURF and KAZE feature descriptors to compute BoW representation of GPGMaps
- Vocabulary built and tested on a variety of datasets recorded on Moon-like Mt. Etna
- Comparison between BoW vector cosine similarity and overlap (IoU) between submaps using ground truth poses
- SIFT features perform generally better than SURF and KAZE, scoring the highest Area under the Curve (AUC)
- BoW similarity proves to be an useful metric to discriminate candidate matching GPGMap pairs



Validation of GPGMap matches

- Candidate GPGMap matches are validated to reject false matches and compute a 4D (x, y, z, yaw) transformation between the original gravity-aligned submap point clouds
- SIFT features are matched between the candidate pair GPGMap1 and GPGMap2
- The RANSAC approach in our previous work [3] is employed to determine an SE(2) transformation between gradient images, without optimizing for scale, which is fixed given the set resolution. The RANSAC model employs also a second error term based on a difference of aligned gradients weighted using the GP covariance
- The affine transformation between gradient images is transformed to the submap domain given the resolution of gradient images
- Point clouds are first transformed using the estimated rototranslation and then aligned in the z direction
- A final ICP refinement constrained to 4D returns the final transformation between the original submaps
- The resulting inter-submap constraint is added to a non linear pose graph

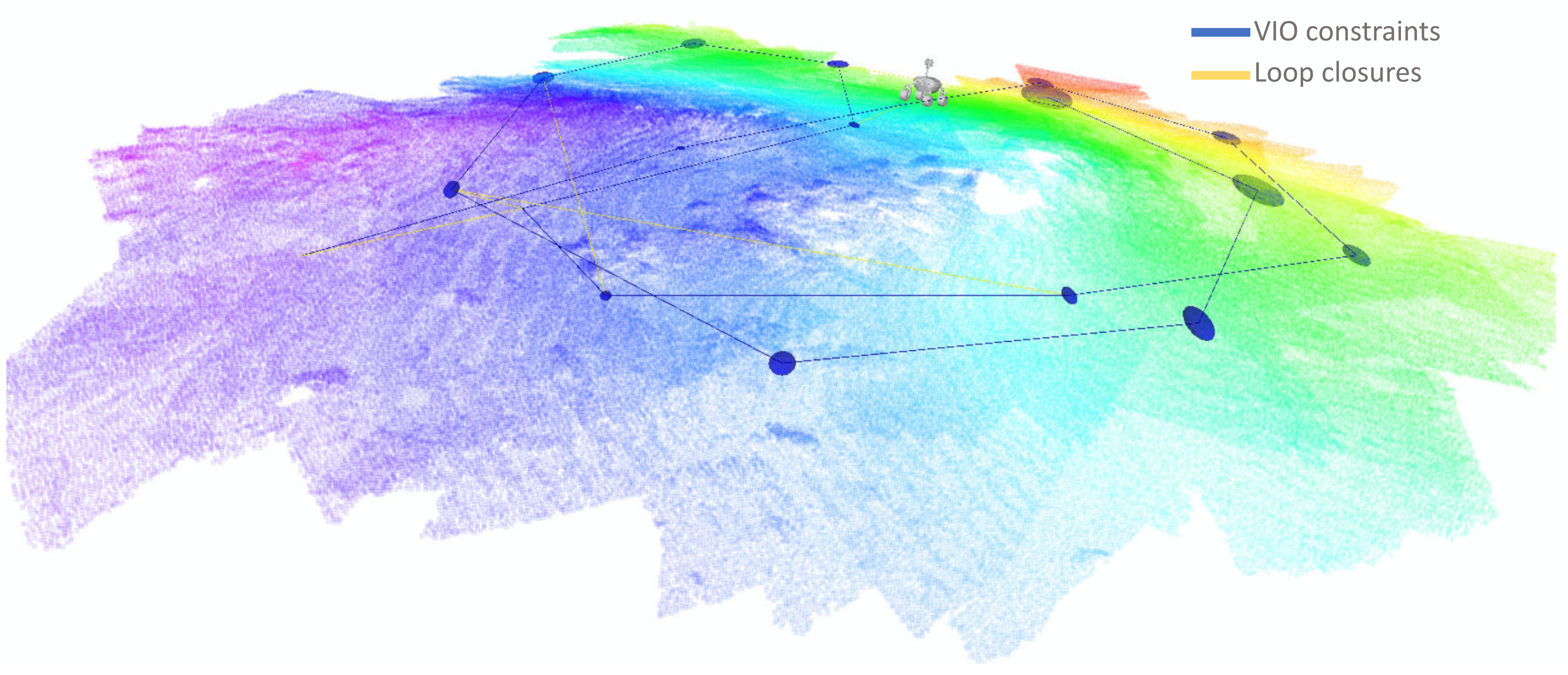


References

- [1] M. J. Schuster, et al., “Distributed stereo vision-based 6d localization and mapping for multi-robot teams,” Journal of Field Robotics, 2019
- [2] A. Wilson et al., “Kernel Interpolation for Scalable Structured Gaussian Processes (KISS-GP),” ICML, 2015
- [3] C. Le Gentil, et al., “Gaussian process gradient maps for loop-closure detection in unstructured planetary environments,” IROS 2020
- [4] A. Wedler, et al., “First results of the ROBEX analogue mission campaign: Robotic deployment of seismic networks for future lunar missions,” in 68th International Astronautical Congress (IAC), 2017

Online GPGM-SLAM test on a Moon-like scenario

- We test GPGM-SLAM on a recorded sequence on a volcanic environment [4] offering multiple GPGMap matching opportunities
- Challenging environment due to repetitiveness and ambiguity of appearance and structure
- Compare with our previous pipeline based on matching point clouds, selected from geometric priors using 3D features [1]
- GPGM-SLAM detects and validates 3 to 4 submap matches, without relying on geometric priors, while our previous pipeline validates only 1 to 2 submap matches
- Robust Cauchy loss applied to the factors in the non-linear graph nullifies the effect of wrong matches



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