Bidirectional Loop Closure Detection on Panoramas for Visual Navigation

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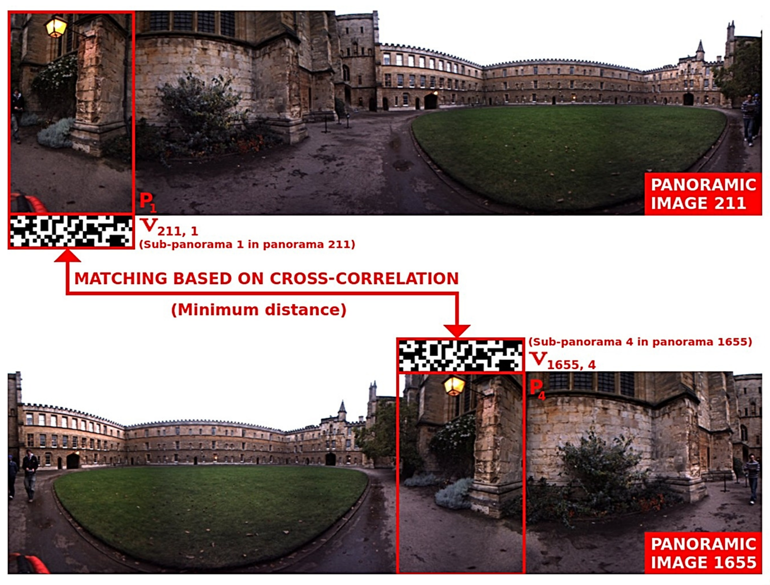
Problem description and system overview

- Loop closure detection consists on **identifying previously visited places.**
- Loop closures can be classified into:
  - **Unidirectional:** a place is revisited in the same direction.
  - **Bidirectional:** a place is revisited in a different direction.
- State-of-the-art algorithms are focused on unidirectional loops, but we propose a novel system for also detecting bidirectional loop closures in **panoramic image sequences.**

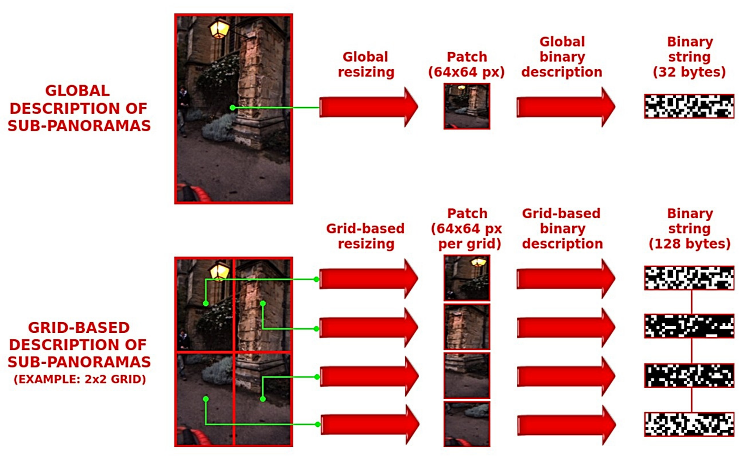


Proposed method (ABLE-P)

- **ABLE** (**A**ble for **B**inary-appearance **L**oop-closure **E**valuation) is the name assigned to our method for a better referring. Furthermore, in this case, it is applied on panoramas, so this specific approach is called **ABLE-P**.

Image description

- A **global binary image descriptor** is computed for each sub-panorama. We also test a grid-based approach.



- The binary descriptors applied are: **ORB, BRISK, FREAK and LDB.**

Image matching

- A matching method based on the **cross-correlation** of sub-panoramas is proposed for detecting loop closures in different directions.
- A cross-correlation matrix (*C*) is filled with the distances between the sub-panoramas of two panoramas. The minimum value of *C* is saved in the distance matrix (*M*) as the final similarity between the pair images.

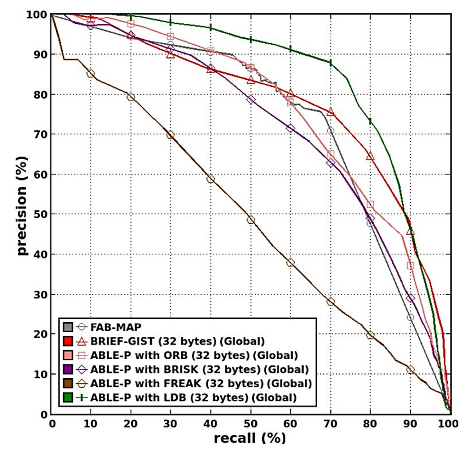
$$C_{k,l} = C_{l,k} = \text{bitsum}(\mathbf{v}_{i,k} \oplus \mathbf{v}_{j,l})$$

$$M_{i,j} = M_{j,i} = \min(C)$$

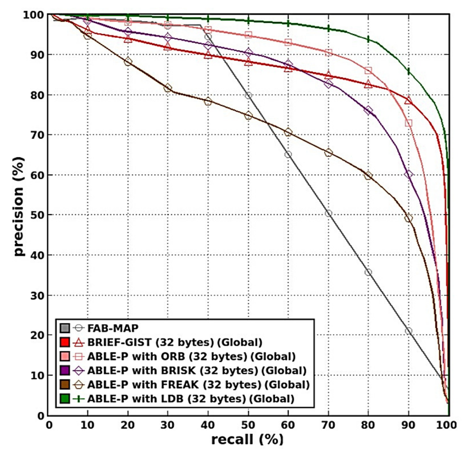
$$M_{i,j} = \frac{M_{i,j}}{\max(M)}$$

Experimental results

Results for only unidirectional loop closures



P-R curves for unidirectional loops in the Ford Campus dataset.

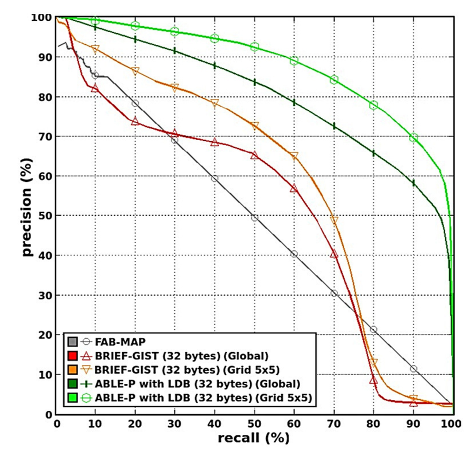


P-R curves for only unidirectional loops in the Oxford New College dataset.

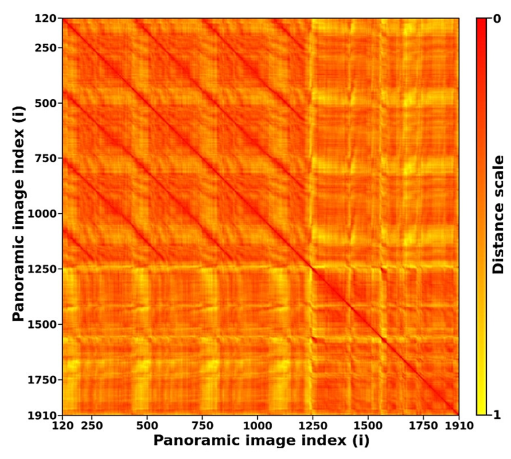
		Average precision	Time per description	Time per matching
FAB-MAP		70.90 %	167.49 ms	$1.31 \cdot 10^{-2}$ ms
BRIEF-Gist		87.58 %	0.04 ms	$2.35 \cdot 10^{-5}$ ms
ABLE-P	ORB	89.33 %	0.17 ms	$2.33 \cdot 10^{-5}$ ms
	BRISK	84.38 %	0.18 ms	$2.61 \cdot 10^{-5}$ ms
	FREAK	72.36 %	0.38 ms	$2.66 \cdot 10^{-5}$ ms
	LDB	95.74 %	0.11 ms	$2.29 \cdot 10^{-5}$ ms

Comparison of some performance parameters between the approaches tested in unidirectional loop closure detection.

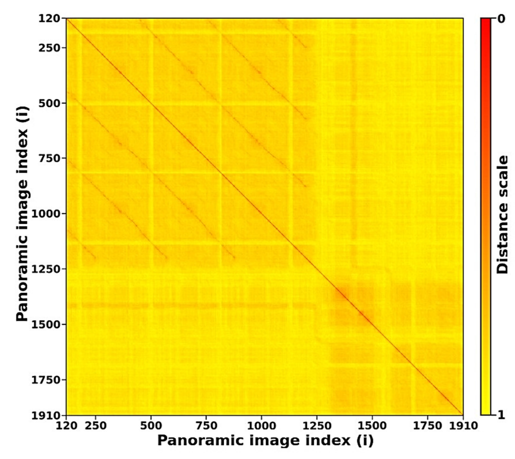
Results for unidirectional and bidirectional loop closures



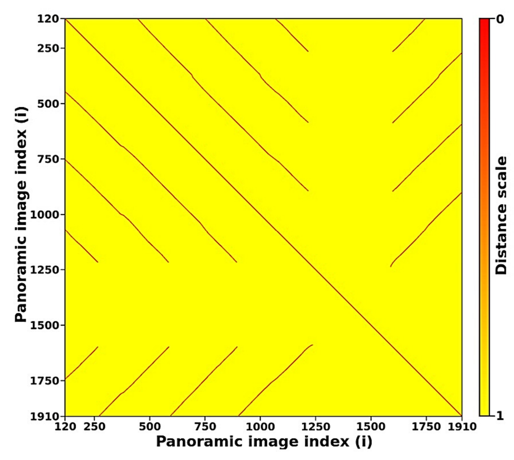
P-R curves



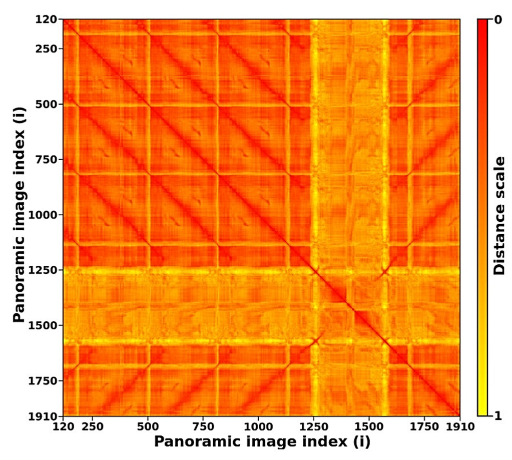
M using BRIEF-Gist (Global)



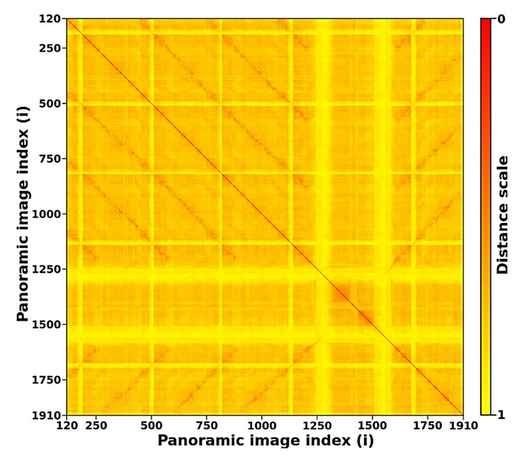
M using BRIEF-Gist (Grid 5x5)



Distance matrix (M): ground-truth



M using ABLE-P with LDB (Global)



M using ABLE-P with LDB (Grid 5x5)

NOTE: the previously showed distance matrices correspond to the tests carried out in the Oxford New College dataset between images 120 and 1920, considering unidirectional and bidirectional loop closures. Distance matrices and P-R curves demonstrate that our method can detect bidirectional loop closures while BRIEF-Gist can not detect them.

Conclusions

- **ABLE-P improves the results** yielded by other state-of-the-art methods, such as FAB-MAP or BRIEF-Gist, specially for bidirectional loops.
- **Binary descriptors** are an excellent tool for describing places **(specially LDB)** because of its great precision and low computational cost.
- **Cross-correlation** of sub-panoramas allows to match bidirectional loop closures.

Future works

- Usage of **3D information** in image description and **KNN-based matching** for improving loop closure performance in **life-long navigation.**
- We will be presenting a related work entitled "**Fast and Effective Visual Place Recognition using Binary Codes and Disparity Information**" on September in IROS 2014. More info at:

www.robesafe.com/personal/roberto.arroyo/

Acknowledgments

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