LIFE-LONG VISUAL LOCALIZATION USING PROBABILISTIC TEMPORAL INFERENCE

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ABSTRACT

Life-long visual localization is a challenging computer vision topic because of the strong appearance transformations that a place usually suffers due to geometric changes, dynamic elements, weather or seasons. We have designed a method named ABLE which can visually recognize locations at different times of day, along the months or seasons. Our current objective is also the application of a probabilistic detection of geometric changes across the four seasons in 3D reconstructed environments.

MOTIVATION AND OVERVIEW

The main goal of our research is to re-identify places using visual information and to detect changes in these locations, which are critical tasks in any visual localization system. Besides, a temporal inference based on probabilities can help to reduce the uncertainty associated with **large-scale problems**.

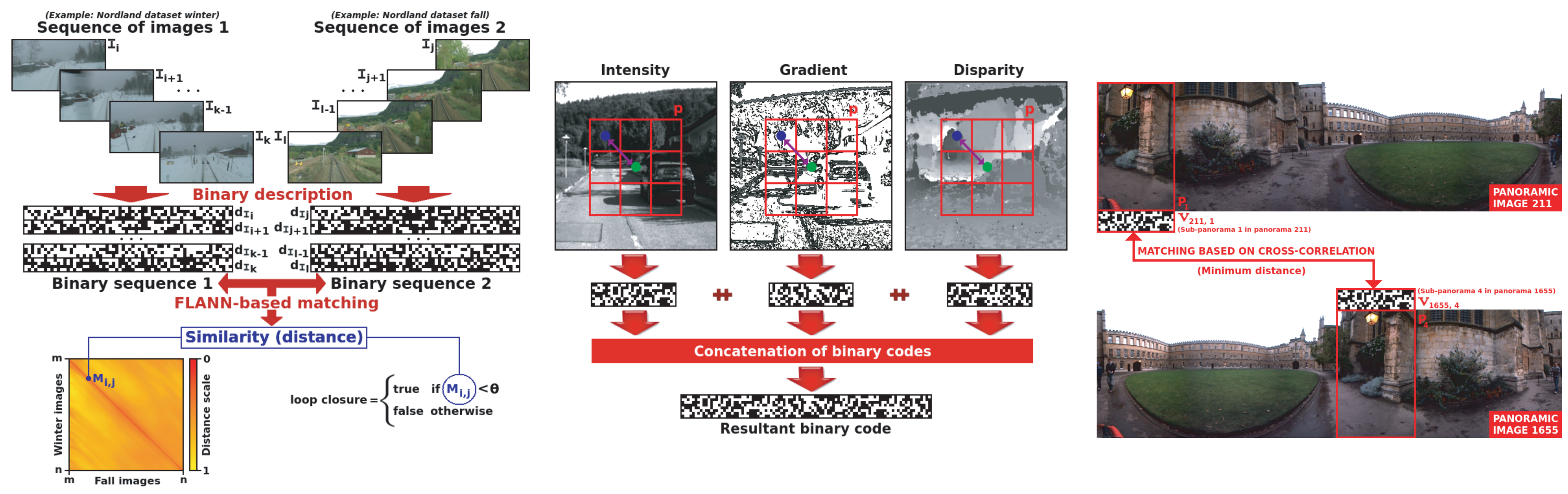
Nowadays, state-of-the-art works are starting to study the difficulties of **visual localization in a long-term context**. As the most representative example, **seasonal changes** produce drastic modifications in the visual appearance of places.

a) Spring b) Summer c) Fall d) Winter

Fig. 1. An example of seasonal changes in a same place in the Nordland dataset.
The Nordland dataset is available in:
https://nrkbeta.no/2013/01/15/nordlandsbanen-minute-by-minute-season-by-season/

OUR METHOD FOR VISUAL PLACE RECOGNITION: ABLE

ABLE (**A**ble for **B**inary-appearance **L**oop-closure **E**valuation) is our proposal for re-identifying places using only visual appearance. Images are described as binary codes extracted from a global **LDB** (Local Difference Binary) descriptor and efficiently matched using FLANN. This approach provides a **great reduction of memory and computational costs**, which is necessary for long-term performance.

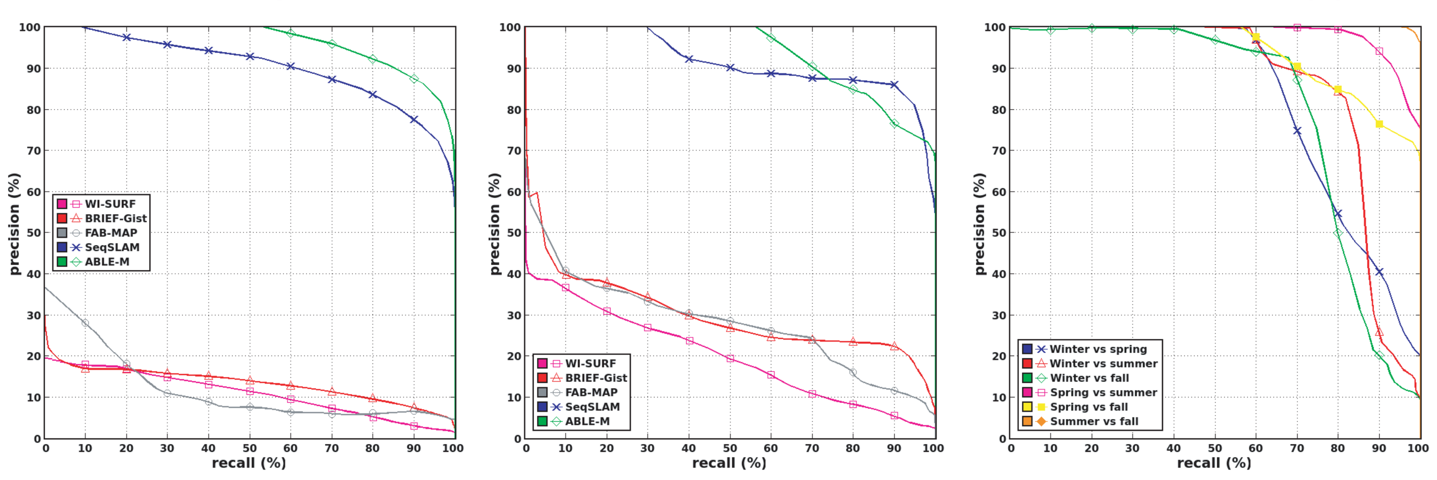


a) ABLE-M [1] (Monocular images) b) ABLE-S [2] (Stereo images) c) ABLE-P [3] (Panoramic images)

Fig. 2. The different versions of ABLE. Check out our published material in [1] [2] [3] for a deeper explanation of each approach.

EXPERIMENTAL RESULTS IN VISUAL PLACE RECOGNITION FOR ABLE-M

Our method for place recognition is satisfactorily compared against the state of the art. Evaluation is based on similarity matrices and precision-recall curves. We show results for our last approach: **ABLE-M**. For more tests, see [1] [2] [3].



a) ABLE-M vs state-of-the-art methods (CMU-CVG Visual Localization dataset) b) ABLE-M vs state-of-the-art methods (Nordland dataset) c) ABLE-M performance between seasons (Nordland dataset)

Fig. 3. P-R curves showing the performance of ABLE-M in challenging life-long localization scenarios.

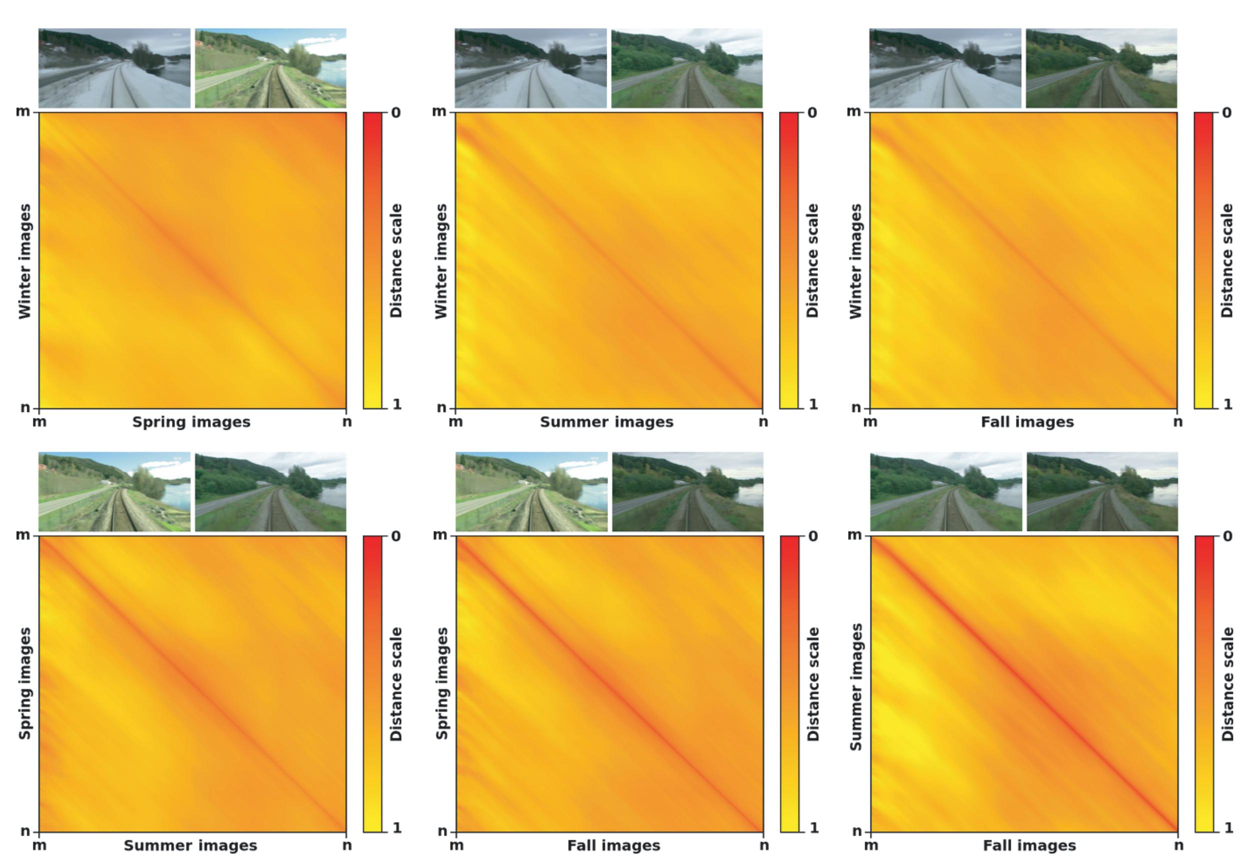


Fig. 4. Similarity matrices showing ABLE-M performance across the four seasons in the Nordland dataset.

Why ABLE-M improves state-of-the-art methods in life-long visual localization?

- **Sequences of images** instead of single images for recognizing places.

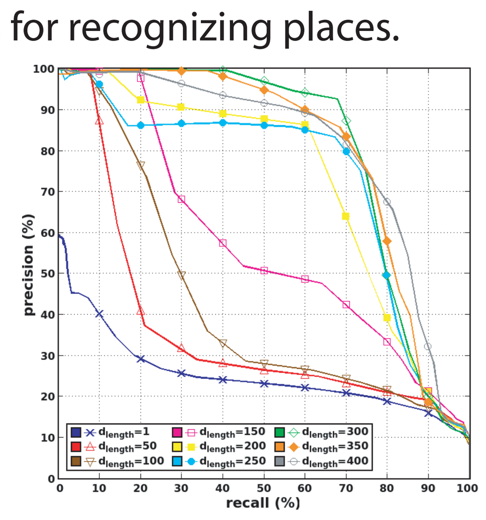
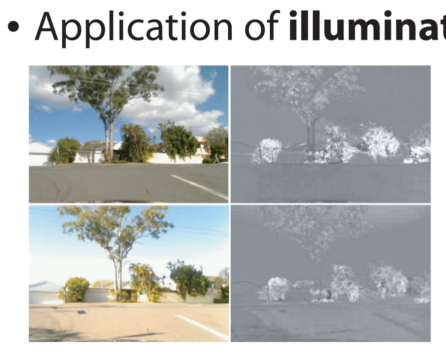


Fig. 5. ABLE-M performance depending on the length of the sequences of images (Nordland dataset).

- Application of **illumination invariance**.



$$\mathcal{I} = \log(G) - \alpha \cdot \log(B) - (1-\alpha) \cdot \log(R) \quad (1)$$

$$\frac{1}{\lambda_G} = \frac{\alpha}{\lambda_B} + \frac{(1-\alpha)}{\lambda_R} \quad (2)$$

$$\alpha = \frac{\left(\frac{\lambda_R}{\lambda_G} - \frac{\lambda_R}{\lambda_B}\right)}{\left(1 - \frac{\lambda_R}{\lambda_B}\right)} \quad (3)$$

Fig. 6. Example of illumination invariance usage and basic formulation for RGB invariant transformation.

- The **binary descriptors** applied by ABLE-M jointly with the matching based on **Hamming distance and FLANN** provide a remarkable performance and low processing times.

FUTURE WORK: CHANGE DETECTION

The **detection of geometric changes** in places traversed on different months of the year is the future goal of our research.

3D reconstructions of the environment are carried out in different periods of time. After that, a grid mapping comparison based on probabilistic temporal inference is performed with the aim of evaluating the geometric changes that a place has suffered along the time.

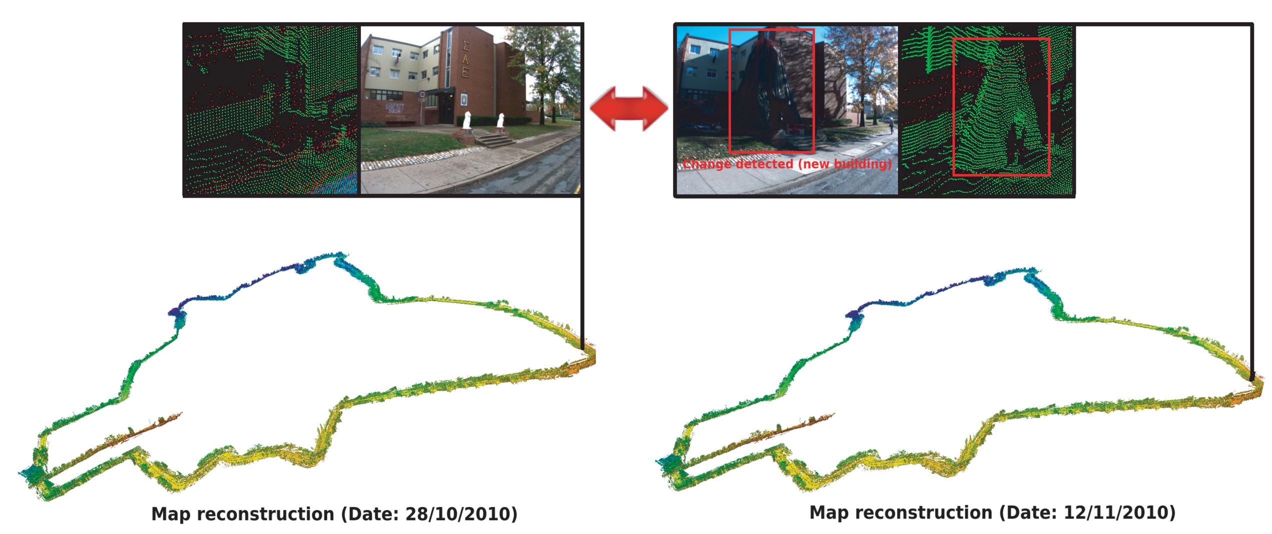


Fig. 7. An example of geometric change detection in the CMU-CVG Visual Localization dataset.
The CMU-CVG Visual Localization dataset is available in:
http://3dvis.ri.cmu.edu/data-sets/localization/

CONCLUSIONS

Our work contributes an innovative approach for visual localization, which has been successfully tested in life-long scenarios. Besides, ABLE is an efficient alternative to state-of-the-art methods.

For more information about our work, please visit this Webpage:
http://www.robesafe.uah.es/personal/roberto.arroyo/

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ACKNOWLEDGEMENTS

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