EE5346 - Autonomous Robot Navigation

Spring 2023
Project Description
Robust Verification in Loop Closure Detection and Visual Place Recognition

Overview

Loop closure detection (LCD) refers to the event when a robot returns to a previously visited location [1], and it is an important component in a SLAM algorithm whereby long-term drift of robot pose can be corrected. Similarly, visual place recognition (VPR) is the problem of determining whether a query image can find a match in a database of images that have been historically collected [2]. LCD and VPR are two intimately related problems, although LCD is defined only in the context of visual SLAM, whereas VPR has broad applications in robotics and computer vision. Both problems have been similarly studied and the solutions are similar where an algorithm first finds likely candidates among map/database images, and then verifies if any of the top candidates is indeed the correct answer (a closed loop or recognized place). Our course project is concerned with a study of a robust verification method for LCD and VPR. Specifically, you will review the current literature on LCD/VPC and explores one of two possible methods that can improve the state-of-the-art on the current verification procedure, in terms of overcoming the limitations of the current verification method with respect to handling views that are significantly different in illumination or viewpoint or both. The technique to be explored will be inspired by exploiting depth information available, as is the case of loop closure detection in visual SLAM, or recent learning-based solutions to image matching. The project will begin with a proposal of your plan about how you will undertake the project and will culminate with a report in the form of a research paper and its oral presentation to the class.

Description

The project will proceed in the following steps.

1. You will begin your project by first understanding the problem of visual loop closure detection and place recognition and the verification step in their solutions. Then, as Part I of the project, you will need to implement a baseline that uses a standard technique for loop closure verification based on feature extraction and matching, and multi-view geometry, on a small dataset (freiburg1_room sequence of the TUM dataset or the mini RobotCar [3] dataset).

2. Concurrently, you will then develop a project plan/proposal and describe how you will approach the problem of improving the existing loop closure verification solutions. Your proposal should contain details information about the project including its focus, the algorithms/methods you plan investigate, the datasets on which to conduct experiments [1], and milestones. The format of the proposal will be announced separately.

3. Part II of the project is regarding the improved algorithm/method on loop closure verification. As the first option, you can explore how depth information - which is uniquely available from a typical visual SLAM algorithm or through a depth sensor (RGB-D or stereo vision) - can be

used to address the challenge of matching image pairs with significant viewpoint or illumination changes. Note that depth is typically unavailable in the standard image matching task but is readily available in visual SLAM, through either a sensor or visual odometry and SfM.

4. Alternatively, if you have adequate background and experience in deep learning, you can investigate the effectiveness of the latest learning-based solutions to image matching found through the CVPR 2022 Image Matching Challenge website. Learning-based methods for image matching and motion estimation have been developed in the past few years and are known to outperform the traditional methods based on handcrafted features. It is worthwhile to investigate how the verification of loop closure and place recognition can benefit from these methods. We suggest that you limit considerations to: LoFTR, SuperPoint/SuperGlue, DKM , and QuadTreeAttention. See lecture notes for details of these works.

5. Upon completion of the experimental study, document the results and findings in the form of a research paper in IEEE two-column format with 6-8 pages, and present it to the class on the last days of the class. Use either the Word or LaTex template.

Dates

Written proposal	April 29
Proposal presentation	May 6 (10 minutes/group)
Project presentation/demo:	May 29/31 (20 minutes/group)
Written project report:	June 5

Marking

Proposal/report:	10%
Baseline (Part I):	30%
Complete solution (Part II):	30%
Novel contribution (Part II):	30%

References

[1] Tsintotas, Konstantinos A., Loukas Bampis, and Antonios Gasteratos. "The revisiting problem in simultaneous localization and mapping: A survey on visual loop closure detection." *IEEE Transactions on ITS* 23.11 (2022): 19929-19953.

[2] Lowry, S., Sünderhauf, N., Newman, P., Leonard, J. J., Cox, D., Corke, P., & Milford, M. J. (2015). Visual place recognition: A survey. IEEE *Transactions on Robotics*, *32*(1), 1-19.

[3] Maddern, Will, et al. "1 year, 1000 km: The Oxford RobotCar dataset." *The International Journal of Robotics Research* 36.1 (2017): 3-15.