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PROPOSITION DE STAGE EN COURS D'ETUDES

Référence : **DTIS-2021-12**
(à rappeler dans toute correspondance)

Lieu : Palaiseau

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DESCRIPTION DU STAGE

Thématique(s) : Robotique et Autonomie

Type de stage : ☒ Fin d'études bac+5 ☒ Master 2 ☐ Bac+2 à bac+4 ☐ Autres

Intitulé : Motion planning for autonomous robots from semantic information

The context of this work is the autonomous navigation of ground and aerial robots in challenging environments (indoor, cluttered, unknown) for exploration purposes. More specifically, the applications targeted are the autonomous coverage of large unknown, cluttered GNSS-denied indoor and outdoor environments, which includes in particular Planetary Exploration as well as Reconnaissance or Search and-Rescue operations. Several strategies have been developed and tested experimentally in the past few years, in particular for vision-based localization and environment modeling which are used on-board of the robots to safely navigate and provide feedback on realization of tasks. Classical mapping approaches build occupancy grids (see e.g. the widely-used Octomap structure [1]) or surfacic representations (e.g. using truncated signed-distance functions TSDF [2]), mainly for visualization or the evaluation of occupied and free volumes to carry out robot navigation using reactive control or path planning methods.

The task of Semantic Mapping does not only include the creation of a 3D representation of the surrounding environment, but also the categorization of the perceived 3D points. As a result, such a map does not just contain the information about space occupancy or the shape of the surfaces, but also the type of object at this location. Therefore, Semantic Mapping can significantly increase the level of autonomy of systems. For instance, it could be an important part of a mobile robot to improve its localization and navigation capabilities, both indoors or outdoors. Indeed, with the help of semantic labels, maps can be composed more accurately and more robustly against failures, such as wrong loop closures or mismatched features. Particularly for outdoor mobile robots, such maps can help them traversing more safely and efficiently through complex terrain by avoiding loose or dirt surfaces and obstacles like rocks or ditches. The data gathered by the embedded payload sensors can also be included in such a representation, to guide the mission autonomously. Several steps are needed to build a reliable autonomous navigation system based on a semantic representation: data generation and simulation tools, formalization of the semantic map structure itself with an efficient on-board implementation in mind, and the development of path planning methods exploiting semantic information.

In this internship topic, the focus is put on the definition and testing of a navigation architecture including a planning algorithm which exploits information from a semantic mapping algorithm for a simple navigation task (e.g., reach a given location or cover classes of interest while avoiding a variety of obstacles or unreachable areas). The design of motion planning algorithms which can make an efficient use of semantic information is an open issue (preliminary works can be found in [3,4,5,6]). The idea here would be to adapt graph-based techniques (such a RRT and PRM [7,8]) so that they can exploit dynamically various semantic information. This can take the form of either constraints for robot navigation (e.g. traversability) or mission objectives when semantic classes are related to the mission payload (e.g. the observation of areas of interest for scientific or reconnaissance purposes). Regarding the mapping algorithm, even with a good learning structure and enough data it is not straightforward to incorporate semantic information into a 3D reconstruction. Indeed, an approach that directly projects semantic labels over a volumetric representation as in [9,10] is a first possibility, however it cannot be easily used by a motion planning module. A more adapted structure could be a hybrid between dense labelisation and object/instance segmentation, but this remains to be investigated.

In practice, the following tasks are foreseen during the internship:

- A state of the art of semantic mapping approaches that can be used in a robot navigation architecture, in particular by path or motion planning algorithms.
- Define one or several architectures linking semantic maps and planning algorithms for different types of scenarios.
- In a simulated environment, evaluate the different semantic planning strategies proposed. For preliminary testing, the simulation environments and semantic representations can be taken from recent benchmark or open challenges released by the robotic community: ECCV 2018 3DRMS Workshop Challenge [11], MIT GOSEEK challenge [12], or the ACRV Robotic Vision Scene Understanding Challenge [13].
- The developments will be carried out in the ROS framework, real-world experiments with mobile robots equipped with vision and depth sensors [14] can be planned depending on the simulation results and on-board capabilities of the proposed solution.

A follow-up of this work is planned in a PhD thesis in cooperation with the DLR institute to continue the exploration of this Research topic, in particular with respect to: the efficient on-board construction of a semantic map, new algorithms for semantic-based path and motion planning with multiple objectives and constraints, and large-scale deployment in real-world experiments with mobile and aerial robots.

[1] A. Hornung, K. M. Wurm, M. Bennewitz, C. Stachniss, W. Burgard, OctoMap: An efficient probabilistic 3D mapping framework based on octrees, Autonomous robots, 34(3), pp 189-206, 2013.
[2] T. Duhautbout, J. Moras, and J. Marzat. Distributed 3D TSDF manifold mapping for multi-robot systems. In 2019 European Conference on Mobile Robots (ECMR), pages 1–8, Sep. 2019.
[3] L. Bartolomei, L. Pinto Teixeira, M. Chli, Perception-aware Path Planning for UAVs using Semantic Segmentation, IROS 2020.
[4] C. Dornhege, P. Eyerich, T. Keller, M. Brenner, and B. Nebel. Integrating task and motion planning using semantic attachments. In Workshops at the Twenty-Fourth AAAI Conference on Artificial Intelligence, 2010.
[5] Y. Kantaros and G. J. Pappas. Optimal temporal logic planning for multi-robot systems in uncertain semantic maps. In IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pages 4127–4132. IEEE, 2019.
[6] V. Vasilopoulos, G. Pavlakos, K. Schmeckpeper, K. Daniilidis, and D. E. Koditschek. Reactive navigation in partially familiar planar environments using semantic perceptual feedback. arXiv preprint arXiv:2002.08946, 2020.
[7] S. M. LaValle, Planning algorithms, Cambridge university press, 2006.
[8] K. Hauser, Lazy collision checking in asymptotically-optimal motion planning. In IEEE International Conference on Robotics and Automation (ICRA), pp. 2951-2957, 2016.
[9] M. D. de Carvalho, M. Ferrera, A. Boulch, J. Moras, B. Le Saux, and P. Trouvé-Peloux. Technical report: Co-learning of geometry and semantics for online 3d mapping. ArXiv, abs/1911.01082, 2019.
[10] A. Rosinol, M. Abate, Y. Chang, and L. Carlone. Kimera: an open-source library for real-time metric-semantic localization and mapping. ArXiv, abs/1910.02490, 2019
[11] http://trimbot2020.webhosting.rug.nl/events/3drms/challenge/
[12] https://github.com/MIT-TESSE/goseek-challenge
[13] https://evalai.cloudcv.org/web/challenges/challenge-page/625/overview
[14] www.onera.fr/copernic

Méthodes à mettre en oeuvre :

☒ Recherche théorique	☐ Travail de synthèse
☒ Recherche appliquée	☐ Travail de documentation
☐ Recherche expérimentale	☐ Participation à une réalisation

Possibilité de prolongation en thèse : **Oui**

Durée du stage : Minimum : 5 mois Maximum : 6 mois

Période souhaitée : A partir de février 2021

PROFIL DU STAGIAIRE

Connaissances et niveau requis :	Ecoles ou établissements souhaités :
Robotique, ROS, Programmation Objet (Python, C++). Bases de théorie des graphes, traitement du signal et des images. Bon niveau rédactionnel, bon niveau d'anglais	Dernière année d'école d'ingénieur et/ou Master 2 Recherche avec spécialisation en robotique, automatique, traitement du signal et des images.