Subject: 3D mapping and (3D + t) spatio-temporal semantic analysis of indoor environment using colored point clouds acquired by a handheld sensor: 3D convolutional neural networks approah

Supervisor: Paul CHECCHIN (Full Professor)
Laboratory: Institut Pascal – Axe ISPR – PerSyst Team – UMR CNRS 6602
Email and phone: paul.checchin@uca.fr / +33 4 73 40 75 92
Co-advisor: Laurent TRASSOUDAINE (Full Professor)

Abstract (up to 10 lines):
Many 3D datasets, continuous sequence of 3D point clouds or LiDAR scans, are only processed scan by scan by 3D semantic algorithms. In this work, we plan to use 4-dimensional convolutional neural networks to conduct a spatio-temporal analysis. We wish to validate this approach by performing 3D semantic segmentation of digitized interior scenes using a hand-held sensor acquiring colored 3D point clouds. In particular, we will seek to show that 4D space-time convolutional neural networks are robust to noise, outperform 3D convolutional neural networks and are faster than their 3D counterparts. In parallel, we will seek to implement an end-to-end learnable, multiview 3D point cloud registration algorithm to improve the mapping of environment and the 3D localization of the sensor.

Skills required:
Advanced and certified notions in Machine Learning.
Proven skills in computer programming and programming languages (Python, C ++, Pytorch).
Very good knowledge in mathematics (matrix calculation, optimization, graph theory).
Very good English level (level C1 would be appreciated).

Keywords:
3D perception, 3D reconstruction 3D, (3D+t) or 4D perception, 3D point clouds, unsupervised learning, ML Learning, convolutionnal neural networks.

Description (up to 1 page):

The accurate localization of a vehicle or a mobile robot is now very efficient. In outdoor environment, the use of GPS combined with vehicle models are two key factors for

such an achievement. When the city-dweller leaves public transport or his own vehicle to become a pedestrian in order to enter the building by having more random movements, these two facilities disappear. It is important to consider continuity of service in terms of localization assistance and guidance.
The demand for 3D realistic urban models and landscape analysis for different popular applications has tremendously increased in the past few years. Obtaining 3D digital models is therefore also necessary on a lower scale than that of the city. The availability of maps inside shopping centers, airports, factories are sources of many other applications ranging from entertainment to risk analysis. Moreover, different map representations have been considered: metric (or feature based) 3D maps represented as a set of 3D points (plus color information), in contrast with maps represented as a set of semantic structural elements (i.e. floors, walls, steps, stairs, etc.) [1].

The goal of this PhD thesis is to use a perception system that can achieve autonomous semantic 3D mapping of an unknown indoor area. To do this, a process locates the multi-sensory sensor which collects colored 3D point clouds. The ambition of this action resides on the one hand in the accurate localization of the pedestrian in this non-cooperative environment with inexpensive and minimally invasive equipment. On the other hand, the 3D mapping must be sufficiently rich for a later use. But the innovative character of this proposal is to take advantage of the latest advances in work in the field of convolutional neural networks to perform these tasks. Very recently, the possibility of applying proven approaches on 2D images to 3D point clouds was obtained [2]. It made it possible to carry out the semantic analysis of urban scenes in particular. The first publication to use point cloud sequences for the previous exercise was presented at CVPR2019 [3]. At the same time, the first End-to-End learning algorithm for 3D registration [4] has just significantly outperformed the state-of-the-art methods, while being less costly in computation time. The extension of this work to process data on the fly and the study of these machine learning solutions would allow us to foresee major repercussions in the field of 3D mapping and 3D localization [5].

The issues presented above fit perfectly into Challenge 2 of the I-SITE CAP2025 project and more precisely with the two themes "Vehicles and Intelligent Machines" and "Industry of the Future". Jointly, this issue is closely linked to the FactoLab laboratory I partnership with MICHELIN Group. The expected benefits will directly concern the work in progress within the project of autonomous manipulative carriages (Automated Guided Vehicle - AGV).

References:

[1] Julia Sanchez, Florence Denis, David Coeurjolly, Florent Dupont, Laurent Trassoudaine and Paul Checchin, "Robust Normal Vector Estimation in 3D Point Clouds through Iterative Principal Component Analysis.", in ISPRS Journal of Photogrammetry and Remote Sensing, Vol. 163, May 2020, Pages 18-35, 2020. https://doi.org/10.1016/j.isprsjprs.2020.02.018.
[2] Choy, Christopher, Jaesik Park, et Vladlen Koltun. « Fully Convolutional Geometric Features ». In Proceedings of the IEEE International Conference on Computer Vision, 8958–8966, 2019.
[3] Choy, Christopher, JunYoung Gwak, et Silvio Savarese. « 4D Spatio-Temporal ConvNets: Minkowski Convolutional Neural Networks ». In 2019 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), 3070 79. Long Beach, CA, USA: IEEE, 2019. https://doi.org/10.1109/CVPR.2019.00319.
[4] Gojcic, Zan, Caifa Zhou, Jan D. Wegner, Leonidas J. Guibas, et Tolga Birdal. « Learning multiview 3D point cloud registration ». arXiv:2001.05119 [cs], 14 janvier 2020. http://arxiv.org/abs/2001.05119.
[5] Clark, William, Maani Ghaffari, et Anthony Bloch. « Nonparametric Continuous Sensor Registration ». arXiv:2001.04286 [cs, math], 8 janvier 2020. http://arxiv.org/abs/2001.04286.

How to candidate?

The candidate must provide a cover letter in addition to the traditional resume and also attach any scientific publications written as (co-)author. The Master internship report will be also communicated. It is requested to quote 3 personalities who recommend you as PhD student.

The documents will be sent to:

paul.checchin@uca.fr
laurent.trassoudaine@uca.fr