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Title of PhD subject: **Co**llaborative Multi-Robot **Per**ception **for** Improved Localization and Semantic **M**apping (**Co-PerforM**)

Summary:

Autonomous robots operating in unknown environments must simultaneously estimate their position and construct a map of the environment. Over the last decade, major advances have been achieved in visual and LiDAR-based SLAM (Simultaneous Localization and Mapping) systems, enabling robust localization and mapping in complex environments. However, most existing SLAM solutions are designed for single-robot systems and remain limited in large-scale or dynamic environments where perception is incomplete due to occlusions, limited sensor coverage, or environmental variability.

Multi-robot systems provide an opportunity to overcome these limitations through collaborative perception. Multiple robots can observe the environment from different viewpoints and share their sensor observations to improve localization accuracy and map completeness. In such systems, some landmarks or objects may be visible to one robot but not to another, while redundant observations from multiple robots can significantly reduce uncertainty.

This PhD project proposes the development of a centralized collaborative localization and semantic mapping framework integrating perception data from multiple robots equipped with heterogeneous sensors such as cameras, LiDAR, and inertial sensors. The system will rely on a centralized mapping architecture that aggregates observations from several robots into a consistent global map. In addition to geometric mapping, the framework will incorporate semantic perception techniques capable of detecting and describing static and dynamic objects within the environment. The central hypothesis of this research is integrating perception information from multiple robots within a centralized cooperative SLAM framework can significantly improve localization accuracy, mapping consistency, and semantic understanding of the environment compared to independent robot mapping.

A key contribution of the project will be the development of cross-validation mechanisms that exploit redundant observations from multiple robots. These mechanisms will improve localization accuracy, increase object detection reliability, and accelerate map construction.

The subject addresses several scientific challenges such as:
– **Robust multi-robot data fusion**, enabling consistent integration of heterogeneous sensor observations collected by different robots.
– **Cross-robot data association**, particularly for landmarks and semantic objects observed from different viewpoints and at different times.
– **Scalable centralized SLAM optimization**, capable of maintaining global consistency as the number of robots and observations increases.
– **Handling uncertainty and dynamic environments**, including the detection and management of moving objects within collaborative maps.

The expected outcomes include new algorithms for centralized multi-robot SLAM, collaborative semantic mapping techniques, and experimental validation on real robotic platforms. These contributions will advance collaborative robotics for applications such as autonomous exploration, industrial inspection, intelligent transportation systems, and safer human–robot cohabitation in industry 5.0.