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- Jury :
    - THIERRY FRAICHARD, Rapporteur, Chercheur à l'INRIA, Grenoble Rhône-Alpes
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    - LOUNIS ADOUANE, Encadrant, Maître de Confèrences - HDR à l'Université Blaise Pascal
    - YOUCEF MEZOUAR, Directeur de thèse, Professeur à l'IFMA
- Résumé de thèse :

Safe and Flexible Hybrid Control Architecture for the Navigation in Formation of a Group of Vehicles

Beyond the interest of robotics laboratories for the development of dedicated strategies for single vehicle navigation, several laboratories around the world are more and more involved in the general challenging field of cooperative multi-robot navigation. In this context, this work deals with the navigation in formation of a group of Unmanned Ground Vehicles (UGVs) dedicated to structured environments. The complexity of this Multi-Robot System (MRS) does not permit the direct use of neither classical perception nor control techniques. To overcome this problem, this work proposes to break up the overall control dedicated to the achievement of the complex task into a group of accurate and reliable elementary behaviors/controllers (e.g., obstacles avoidance, trajectory tracking, target reaching, navigation in formation, formation reconfiguration, etc.). These behaviors are linked to different information given by the sensors to the actions of vehicles. To guarantee the performances criteria (e.g., stability, convergence, state errors) aimed by the control architecture, the potentialities of hybrid controllers (which controlling continuous systems in the presence of discrete events) are considered. This control architecture is validated for a single vehicle to perform safe and flexible autonomous navigation using an appropriate strategy of navigation through suitable set of waypoints. This flexible navigation allows different vehicle maneuvers between waypoints (e.g., target reaching or obstacle avoidance) without using any trajectory planning nor replanning. The designed control law based on Lyapunov synthesis guarantees the convergence to assigned waypoint while performing safe trajectories. Furthermore, an algorithm to select suitable waypoints' positions, named Optimal Multi-criteria Waypoint Selection (OMWS), in structured

environments while taking into account the safe and reliable vehicle movements, and vehicle constraints and uncertainties is proposed. Subsequently, the control architecture is extended to Multi-Robot Formation (MRF) using a combination of Leader-Follower and behavior-based approaches. An important cooperative MRS issues in this thesis is the dynamic reconfiguration of the formation according to the context of navigation (e.g., to pass from a triangle configuration towards a line if the width of the navigation way is not sufficient). The proposed Strategy for Formation Reconfiguration (SFR) guarantees the stability and the safety of the MRS at the time of the transitions between configuration (e.g., line towards square, triangle towards line, etc.). Therefore, a safe, reactive and dynamic MRF is obtained. Moreover, the degrees of multi-robot safety, stability and reliability of the system are quantified via suitable metrics. Simulations and experiments using urban vehicles (VIPALABs) of the Institut Pascal laboratory allow to perform exhaustive experiments of the proposed control architecture for the navigation in formation of a group of UGVs.