The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Kelly Merckaert**

The public defense will take place on **Thursday 11th May 2023 at 5:00pm** in room **I.0.01** (Building **I**, VUB Main Campus)

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CERTIFIED SAFE, FAST AND REAL-TIME ROBOT CONTROL IN WORKSPACES SHARED BY HUMANS AND ROBOTS

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Abstract of the PhD research

Recently, manufacturers require more flexibility in their production environments to enable mass customization. Therefore, they want to exploit the complementary strengths of humans and robots with collaborative robots that work in a constantly changing environment shared with humans, so they must be safe. Currently, these robots are made very slow to be safe, making them less productive and less economically attractive.

The main objective of this PhD dissertation is to investigate whether the performance of a robot manipulator can be improved with real-time control methodologies while certifying safety in dynamic environments cluttered with objects, boosting the productivity of collaborative workstations.

This work extends and specializes the trajectory-based Explicit Reference Governor (ERG) constrained control theory and its two main components, the Navigation Field (NF) and the Dynamic Safety Margin (DSM), to deal in real-time with a generic robot manipulator subject to actuator constraints, joint angle and velocity limitations, Cartesian end-effector velocity constraints, and possibly moving obstacles in the environment. The developed algorithm is validated on the Franka Emika Panda robot and shows a robot that can quickly and safely reach target references while reactively avoiding collisions with static obstacles and humans. However, the more static objects in the environment, the easier the robot can get stuck in local minima, whereby it will not reach the target reference.

To provide global convergence toward the target reference, this work combines the ERG, which guarantees constraint satisfaction in highly dynamic environments but can get trapped in local minima, with a Rapidly-exploring Random Tree (RRT) sampling-based motion planner, which can solve complex path planning problems in cluttered environments but has issues handling dynamic constraints. Therefore, a reference selector is designed that sequentially assigns one of the waypoints generated by the RRT as a target reference for the ERG. The proposed algorithm is validated in different cluttered Human-Robot Collaboration (HRC) environments.

Throughout this PhD, a modular ROS-based system architecture has been developed for the proposed planning and control framework that will be open sourced on GitHub and is accompanied by documentation provided in an online tutorial. This will enable researchers and practitioners to test the proposed framework with exemplary numerical and experimental validation cases and in realistic HRC scenarios, making the research reproducible for a broader community.