Summary

Many wheelchair users face significant challenges in performing daily activities. These difficulties can arise from fatigue due to continuous propulsion of the wheelchair, upper body weakness due to elderly age, or upper limbs pain caused by repetitive strain injuries. Regardless of the cause, these users require assistance to maintain good domestic independence and to actively participate in social activities. Over the years, various alternative solutions to standard handrim-propelled wheelchairs have been developed to improve the propulsion effectiveness and reduce joints load. However, these solutions have often achieved limited success among wheelchair users due to the bulkiness and complexity of the propulsion mechanisms, as well as the lack of intuitive control that don't provide direct haptic feedback. In recent years, several electric propulsion assist devices have been introduced. Many of these solutions completely replace the user's force contribution with electric propulsion devices. However, the medical scientific community agrees on the importance for wheelchair users to engage in daily physical activity, which is beneficial both physiologically and psychologically, making users feel more participative and capable.

In this context, a technological gap has emerged for a solution that provides propulsion and manoeuvring assistance during daily activities. This solution should be suitable to be used in both narrow domestic environments and larger spaces, ensuring continuous active contribution from the user without causing excessive fatigue. During this thesis project, existing devices were evaluated based on multiple significant characteristics, such as size, weight, control method, intuitiveness of command, and influence on psycho-physical effectiveness. Following this evaluation, various positive features from different devices were merged into a novel unique solution and the essential requirements for the new assistive device were defined. The new assistive device concept developed, named ADD-MATE, consists of two sensorized wheels that can estimate the forces exerted

by the user on the handrims and a steerable drive-wheel attached to the rear of the wheelchair frame. The intuitive command method consists in a control system that commands the steering and propulsion motors by interpreting the forces exerted by the user, generating a directed assistive force that aids both propulsion and manoeuvring.

Following the development of the first prototype, an initial experimental campaign revealed some structural and control limitations of the device. Consequently, a second version of the device, ADD-MATE 2.0, was designed and developed. This version integrates more advanced control logic based on predictive models for steering angle estimation and optimization models for generating the reference torque signal for the propulsion motor.

After the development of ADD-MATE 2.0, various experimental tests were conducted, selecting four specific tests performed by two subjects with different levels of experience in using both manual wheelchairs and ADD-MATE 2.0. The analysis of the experimental tests revealed that the device features an intuitive control mode and adapts to different users, even when the user had no prior experience. Furthermore, the analysis of the force required by the user to manoeuvre the wheelchair showed that using ADD-MATE 2.0 reduces the user's required force impulse

In conclusion, ADD-MATE 2.0 demonstrated good behaviour in assisting users to perform manoeuvre and propulsion. However an experimental test campaign with a larger number of subjects and trials will be useful to provide a more comprehensive and statistically significant assessment of the device's performance and its benefits for wheelchair users.