Doctoral Dissertation
Doctoral Program in Mechanical Engineering (34th Cycle)

Artificial Intelligence algorithms for environment perception and vehicle state estimation in assisted and autonomous driving

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This thesis work deals with the study, experimental validation and implementation of artificial intelligence algorithms for environment perception and vehicle state estimation in assisted and autonomous driving. As ground vehicles can be subjected to a wide range of demanding maneuvers and driving situations in challenging environments, the development of novel algorithms for those vehicles is becoming increasingly important in the development of systems for assisted and autonomous driving with artificial intelligence, such as lane-keeping assistance and adaptive cruise control. With regard to the automotive engineering, artificial intelligence is especially effective in a wide range of diverse applications, such as black-box modelling of nonlinear systems, obstacle detection, and state estimation, among others.

In detail, an algorithm based on convolutional neural networks and artificial intelligence is presented in this thesis work for the detection of traffic cones in a racing environment. The electric autonomous racing vehicle is instrumented with stereocamera and LiDAR sensors, thus enabling the development of a fully redundant perception pipeline. Moreover, different driving scenarios are considered in the experimental validation of the proposed technique. The application of neural networks to the assessment of vehicle state is also investigated in the present research work. Specifically, intelligent estimators of sideslip angle and longitudinal speed are designed in this thesis, using neural networks and fuzzy logic. Those algorithms are specifically implemented in electronic control units of both a high-performance sports car and an electric racing vehicle. Furthermore, they are widely tested in different driving scenarios and under several road adherence conditions. To this end, a proper road condition identification algorithm is designed.

Although the use of algorithms based on artificial intelligence is currently experiencing a huge research interest, a thorough examination of algorithms for environment perception and vehicle state assessment is a still evolving study area. In addition, because of the wide range of demanding maneuvers that the retained vehicles must perform, the application of such techniques on sports cars and racing prototypes represents a case study in which accurate assessment of vehicle dynamics and characterization of the driving scenario are critical.

Therefore, the main motivation of this thesis work is to create a research effort that will try to bridge the gap on the use of artificial intelligence-based algorithms in environment perception and vehicle state estimation. The proposed approach uses an experimental method while also includes comparisons and case studies to be examined in a scenario that, although not new, is yet underexplored in some of its features. To this end, the thesis is supported by an extensive experimental validation in a variety of driving conditions, with different vehicles.