PhD in Mechanical Engineering

Research Title: Artificial Intelligence in Automotive

Funded by	Politecnico di Torino (Joint Research Projects with Top Universities)

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Context of the research activity	Current research efforts in the automotive sector, both in academia and industry, aim to develop efficient, safe and sustainable vehicles to tackle challenges coming from environment protection, energy conservation, vehicle collision and transit time reduction. In this scenario, intense research activities are focused on the development of electric vehicle and autonomous driving technologies. In this context, the application of Artificial Intelligence (AI) is becoming an enabling factor because of the potentialities and remarkable advantages in terms of performance, efficiency and flexibility of the solutions that are difficult or even not attainable by more conventional means. These techniques allow providing the vehicles of decision-making processes and sophisticated monitoring and sensing strategies, enabling the adoption of innovative solutions in electric and self-driving vehicles. The project is focused on three areas: a) battery State of Charge (SOC) and State of Health (SOH) estimation by means of recurrent Artificial Neural Networks (ANNs). b) sideslip angle estimation and robust positioning by sensors fusion of GPS and inertial measurements by means of deep learning strategies. c) trajectory planning with decision-making processes based on deep learning combined with vehicle dynamic models.

Objectives	The first part of the project focuses on the study of **ANNs to estimate SOC and SOH of lithium batteries**. A variety of architectures will be considered with a particular attention for recurrent ANNs in different configurations (Nonlinear Autoregressive Network with Exogenous Input (NARX), Elman, Multilayer). The techniques will be tested experimentally in a laboratory environment on real case charge/discharge current profiles to evaluate their feasibility in terms of design complexity (time required for ANN training), performance (estimation accuracy and robustness) and computational cost (processor and memory occupation and time of computation) when deployed on real

	Battery Management Systems (BMS). Expected impact: more reliable estimation of SOC and SOH will improve the life of the battery and allow improving the mission planning of the electrical vehicle. The second part deals with **virtual sensing for automotive**. A first objective is the sideslip angle estimation: ANNs will be trained with experimental datasets and will be validated in a real case in collaboration with industrial partners. The main architectures that will be evaluated are Recurrent and Long-Short Term Memory (LSTM) ANNs. Expected impact: an accurate estimate of the sideslip angle will allow improving the vehicle stability by means of more sophisticated control systems. The second part of this topic is focused on the study of robust automotive positioning. The objective is to develop a technique based on the fusion of GPS signal with relative motion sensors such as lateral and longitudinal accelerations, vehicle speed, wheel steer. The approach will exploit ANNs to produce a robust positioning information also when GPS signal is corrupted or unavailable. The ANNs will be trained and tested on a real vehicle. Expected impact: better positioning involves better trajectory planning in autonomous drive systems, better vehicle to vehicle and vehicle to infrastructure interaction. The third part is devoted to the **trajectory planning**. The objective is to develop a new technique allowing to plan the trajectory of the vehicle with decision-making processes based on learning algorithms combined with vehicle dynamics models. ANNs and other deep learning algorithms will be investigated and tested experimentally on a car equipped with image processing. Expected impact: better trajectory planning in mixed autonomous and non-autonomous driving traffic conditions will be essential in the transition between conventional and autonomous vehicles.

Skills and competencies for the development of the activity	Vehicle dynamics. Artificial Intelligence (machine learning, deep learning) for identification, prediction and estimation with classification and regression techniques. Modelling and simulation of mechanical and mechatronic systems for automotive applications.