Modeling and control using neural network: Application to autonomous vehicle

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Context: Recently, the use of artificial intelligence (AI) has taken on paramount importance in various fields: finance, IT, information extraction from large databases, autonomous vehicles, perception, etc. This interest in artificial intelligence is due to the efficiency and performance obtained through this type of data analysis and identification methods. We distinguish the methods of Machine Learning and Deep Learning as the most used tools in AI. They are based on the use of neural networks with several hidden layers allowing to approximate any input-output behavior and to detect the hidden links between several quantities. This makes these methods suitable for modeling dynamic systems and for prediction.
On the other hand, in the field of automation, several approaches dealing with the problems of control, stabilization and observation have been dealt with from a stability point of view (generally with Lyapunov theory). Models in the form of coupled systems of differential equations are then used. These models are generally complex and highly nonlinear, which inevitably leads to simplifications in the dynamics and consideration of only synthetic models. These models are then uncertain with uncertainties affecting more or less the performance of the control and observation approaches. These uncertainties can also appear during the modeling phase with the assumptions of the writing of the models.

Objectives: This master's internship proposes to exploit the performance of neural networks (NN) and to combine these networks with classical modeling in the form of state representation in order to design observers and controllers robust with respect to modeling uncertainties. We therefore expect to achieve better performance compared to that of conventional controllers. The basic idea is, first of all, to start from a very simplified synthesis model and to calculate a controller and an observer for the dynamic system, which is nonlinear and complex. Second, use Lyapunov's theory to provide the stability of the closed-loop system (or state estimation error in the case of the observer). Globally, the general idea resembles to the Michel Fliess' model free control method where he considers an ultra-local model (generally scalar of the first order) and an online estimation of a function describing the behavior of the system. The theoretical results will be applied to the problem of autonomous vehicle control and observation with comparison to existing approaches.

The proposed controller and observer based on NN will be tested in simulation for controlling the dynamics of an autonomous vehicle.

Keywords: Automatic control, Neural Network, Controller and observer design, uncertain dynamical systems, , Matlab/Simulink, Autonomous vehicles.

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