Neural observers for uncertain or unknown dynamical systems: Application to UAVs

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Context: Observing the state of a system plays an important role in control of dynamical systems for industrial applications. From the works of Rudolf Kalman and David Luenberger in 1960s, for linear dynamical systems, several enhancement have been proposed in order to deal with Unknown Inputs (disturbances, faults, neglected dynamics, etc.). Good results have been obtained if the model of the system is perfectly known. However, this is not really the case and the considered models capture only a part of the behavior of the studied system. In this case, the above observers may provide bad estimation results. In order to cope with this problem, nonlinear dynamical models have been considered these last years which allows to characterize the behavior of a system in a large range of operating. Even if the obtained results are acceptable compared to the use of linear models, the complexity of the models make the design of the observers difficult. Therefore, a compromise should be found between the complexity of the model and the fidelity of the behavior representation in order to reduce the design complexity.
Recently, the Artificial Intelligence algorithms have been applied in various domains including the control theory field. The interest of Neural Networks (NN) is to model complex systems only from a set of inputs and outputs. In addition, considering Deep Networks allows to capture very complicated behaviors. In the years 1980, the drawback of the use of Neural Networks is in the fact that it corresponds to a black box modeling and nothing is known inside this box. This is the objective of this internship.

Objectives: The main objective of the proposed internship is the exploration of a hybrid approach combining Neural Networks and differential equations (may be Partial Differential Equations) in order to design observers for strongly uncertain systems or completely unknown dynamics but known model structure. This allows to have a set of state variables having a physical meaning compared to the fully NN modeling. In this case the idea is to construct a Naural observer aiming to estimate the states of the system even the model of the system is unknown or uncertain. Since, the subject is new, some explorations will be done about the following points:

1. Use of the NN for solving ordinary or partial differential equations
2. Use of the NN to filter noisy signals and compute numerically the time derivatives of these signals (with comparisons with respect to existing works)
3. Exploiting the two first points to design Neural observers for dynamical systems
4. Application to the dynamics of a drone.

Key words: Neural Network, Machine Learning, Deep Learning, Dynamical systems, Uncertain systems, Observers and state estimation, UAVs and drones.
Profile of the student: Good skills in applied mathematics, Automatic control and modeling and Matlab programming

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