Supporting Traditional Controllers of Combustion Engines by Means of Neural Networks

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Abstract In this paper it is investigated whether neural networks are able to improve the performance of a PI controller when controlling a combustion engine. The idea is not to replace but to assist a PI controller by a neural co-controller. Three different neural approaches are investigated for this use: Dynamic RBF (DRBF), Adaptive Time-Delay Neural Network (ATNN), and Local Ellipsoidal Model Network (LEMON).

1 Introduction

Developing combustion engines or aggregates of cars like gearboxes, catalytic converters and control boxes means testing them on a testbed. The ability to follow a prescribed speed table with a combustion engine on a testbed with high precision, is one of the main characteristic features of a controller for a combustion engine.

Presently throttle angle based control of combustion engines is done using traditional controllers and inverse engine maps. The inverse engine map is used to predict the throttle angle dependent on the demanded torque. One of the major drawbacks of using inverse engine maps is the high measurement effort, resulting in high stress for the combustion engine.

A problem of traditional controllers is the lack of constant control conditions in steady state. There is always an error between the reference and the measured value due to unsteady torque present in a combustion engine. Another problem using static inverse engine maps are changes within the control box. Gear shifts for instance may cause disturbances of speed and torque.

In this paper we investigate whether the use of neural networks instead of inverse engine maps can help to overcome these problems. As development environment a Matlab/Simulink simulation is used.

In the following, the paper is divided into three parts. First the simulation model is introduced. Then we will describe the applied control strategy as well
as the used neural architectures. Finally, simulation results are presented in the last section.

2 The Simulation

The Simulink simulation model consists of a three phase AC induction machine, a spark ignition engine described by a mean value method and a car model. The spark ignition engine is directly coupled with the induction machine. That means, that there is no real gear-box at the test bed. (See figure 1)

![Simulation Diagram](image)

**Figure 1.** The Simulink simulation of the testbed and the combustion engine

Inputs to the spark ignition engine include: throttle angle, an external load torque and ambient conditions (i.e., atmospheric temperature and pressure). The engine model is physically based and captures the major dynamics (lags and delays) inherent in the spark ignition torque production process. The model takes into account the air and fuel dynamics but it does not attempt to generate torque pulsations due to individual cylinder filling events. The reference value of the spark ignition engine is a speed table, that is included in the car model block.

The AC induction machine is supplied by a three phase current converter with field orientated control (direct flux orientation). The function of the induction machine is to simulate the load of a car, inclusive clutch and gear shifts.

The load of a car, which is the reference value for the induction machine, is generated by the car model. The car model simulates the quasi-stationary torque (rolling resistance, air resistance and break) and the spring- and damping torque of the motor-gearbox system with high torque transients during gear shifts and coupling processes. Inputs to the car model are throttle angle and