MIMO control of advanced engines

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Abstract

This project investigates the possibilities to implement a MIMO-control strategy on the variable valve timing (VVT), throttle and wastegate on an SI-engine. In recent years the demands on performance and cleaning of emissions have increased and better results could be achieved with MIMO-control strategies. The result shows that it is possible to control all three actuators using an MPC-controller in simulation environment.

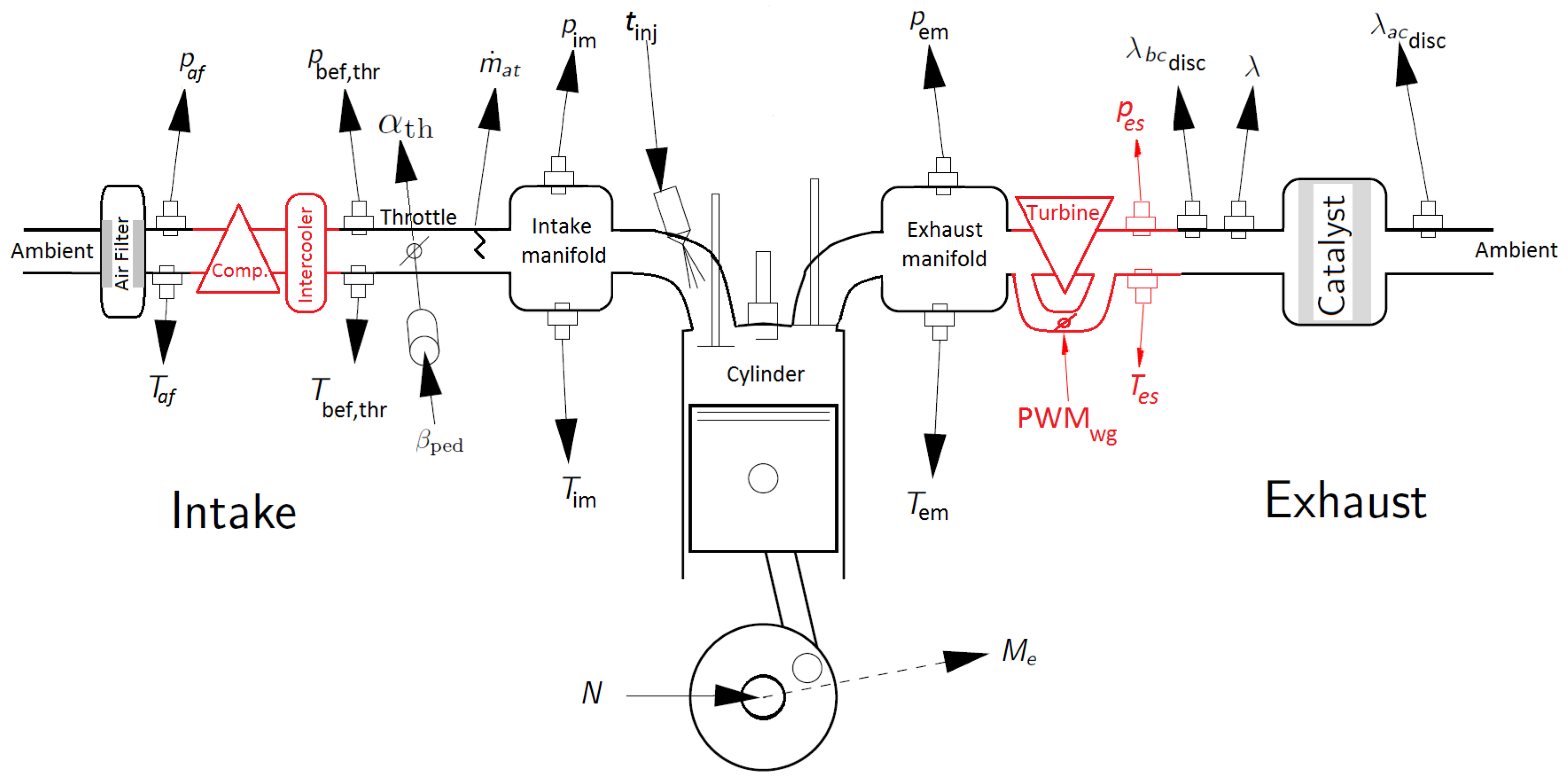

Figure 1: Schematic figure of the different sensors and actuators on an SI-engine.

Actuators and models

The engine has three different actuators, throttle, wastegate and VVT, that can be used to control the air mass flow and are used as control signals by the controller. In this project a model for the VVT has been created. The model is based on residual gas fraction and models the amount of fresh air charge that enters the cylinders. This is highly dependent on the opening and closing times of the valves and also the overlap between the exhaust and intake valves.

QP solver

An MPC-controller uses a quadratic programming solver to find the optimal solution with regards to the goal function and constraints. A solver that converts the QP-problem to a NNLS-problem and then solves it was developed. The structure of the QP solver can be seen in the figure 2.

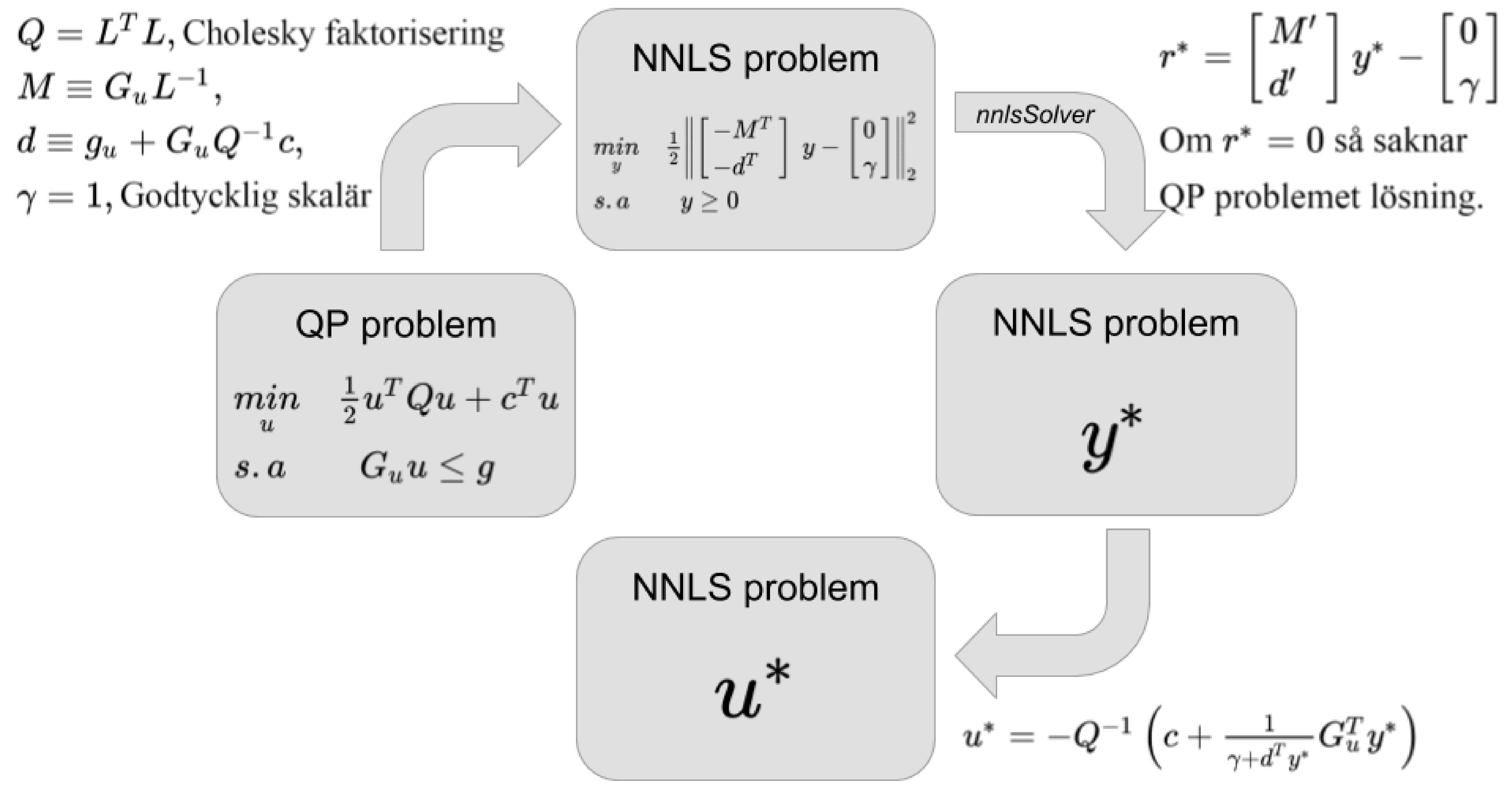

Figure 2: This is the structure of the QP solver.

MPC

The MPC uses a linearized model of the engine and to avoid large static errors a PI controller is used to modify the reference to the MPC. The figure below shows a schematic of the MPC controller. The MPC controller has the following five states

$$x = \left[p_{im}\ p_{ic}\ p_{em}\ p_{es}\ \omega_{tc}\right] \tag{1}$$

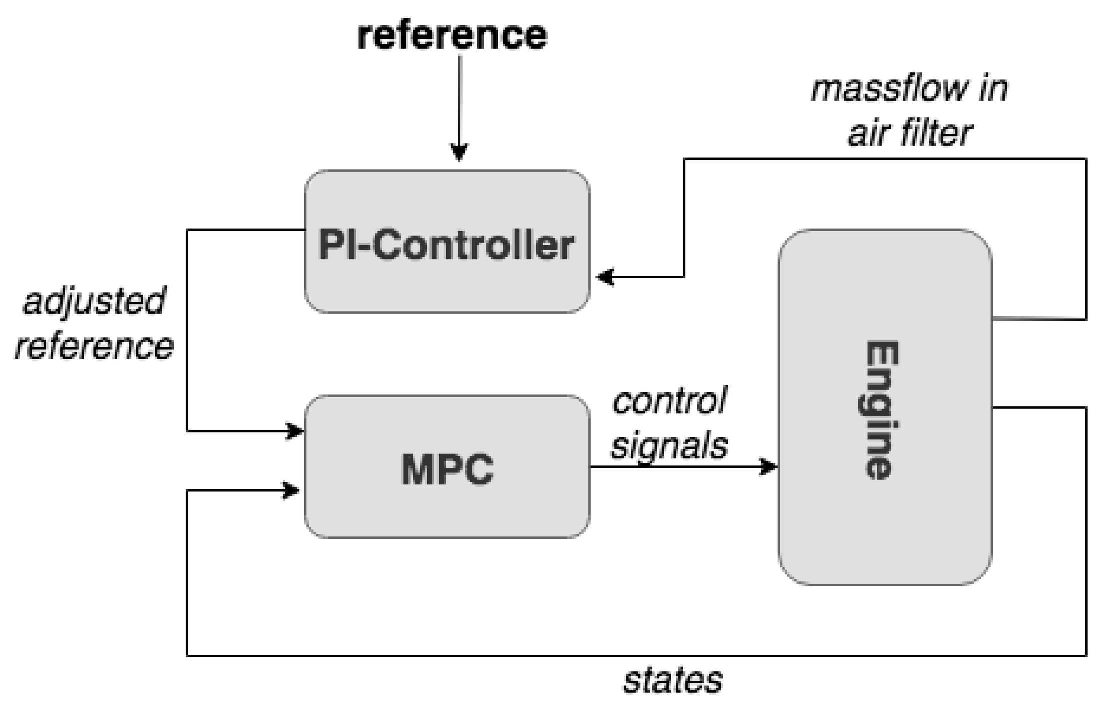

Figure 3: This is the control structure of the MPC-controller.

The goal function that is minimized by the controller is seen in equation (2)

$$J_N(x(k)) = \sum_{j=0}^{N_p-1} \|z(k+j) - r(k+j)\|^2_{Q_1} + \|\Delta u(k+j)\|^2_{Q_2} \tag{2}$$

The goal function penalizes three output signals namely

$$\left[\dot m_{fc} - R,\ \frac{p_{ic}}{\dot m_{fc}},\ \frac{p_{ic}}{p_{im}} - 1\right] \tag{3}$$

For more reading on how MPC could be used in automotive applications see (Bemporad et al., 2018).

Results

In the figures below the results obtained in a simulation with the MPC is shown. The controller follows the requested massflow as seen in figure 4.

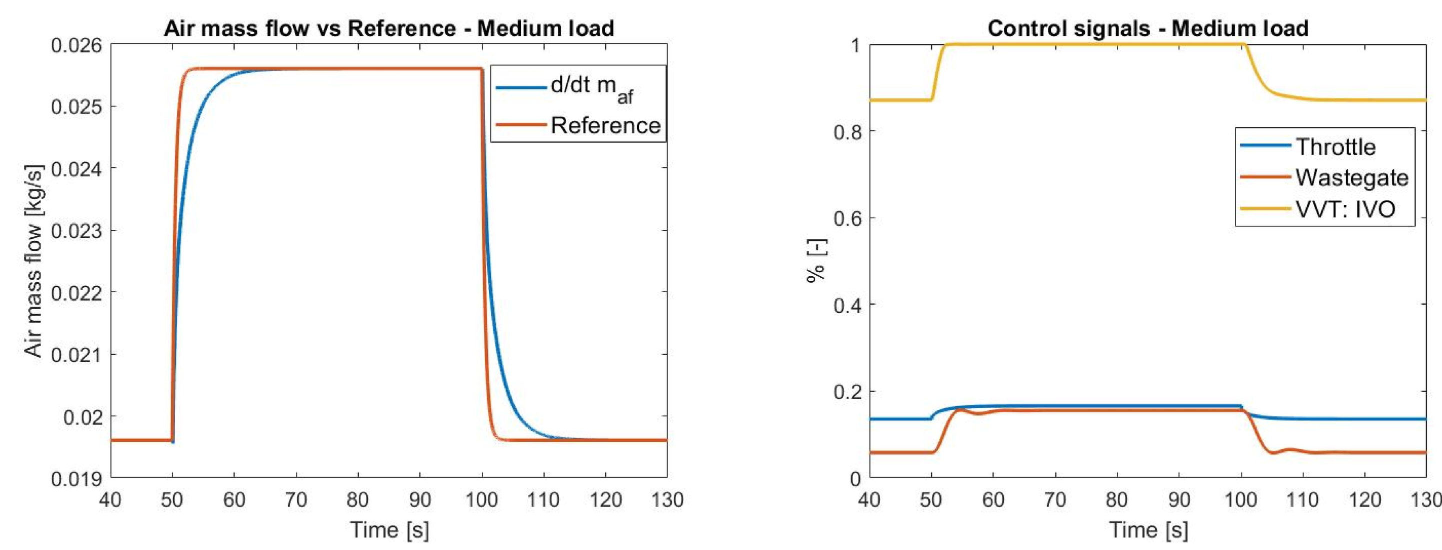

Figure 4: Step in massflow. In the left figure the tracking of the reference is shown. In the right figure the control signals are displayed.

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References

Bemporad, A., D. Bernardini, R. Long, and J. Verdejo 2018. Model predictive control of turbocharged gasoline engines for mass production. SAE International.

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