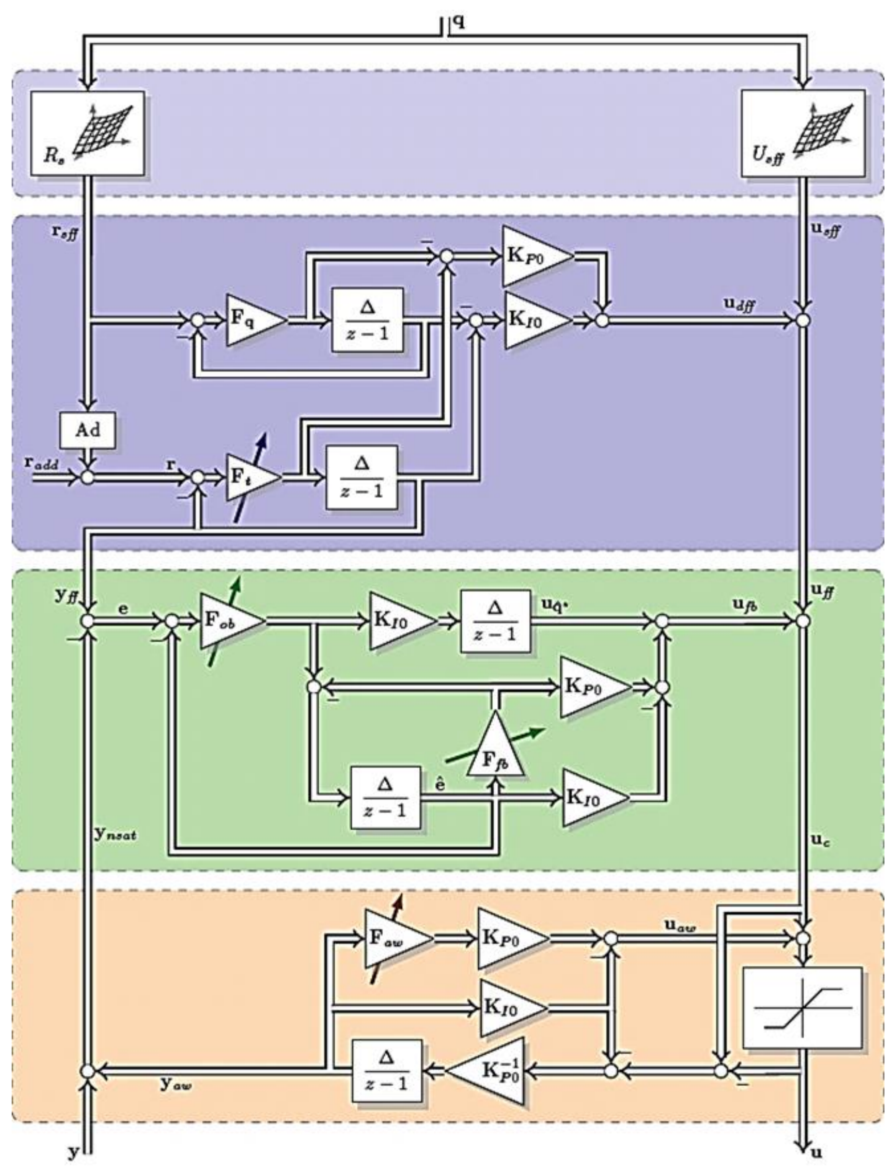
Multivariable Control strategies and modelling

Challenges and solutions:

Real physical systems unfortunately does not follow the education approach of linear systems with decoupled control path. The air path of turbocharged internal combustion engines with EGR is a well known example and object of research & development with respect to controls.
Beside the solution of the control tasks, a straight forward parameter identification and calibration process is requested to enable fast and cost effective application of the control concept.

IMPERIUM's contributions:

A multi-variable air-path control functionality is developed based on following structure. The function main blocks encompass: (Rffs) Static Feed-forward, (Rffd) Dynamic Feed-forward, (Rfb) Feed-back control, (Raw) Anti-Windup part and (Rdel) actuator delays. In this task development focus on an air-path MIMO controller (2 degrees of freedom controller) – controller design.
The algorithm implementation considers controller core and additional functionalities like engine dynamic detection / smoke limitation. Included is also the integration with the engine plant model and setup of model in the loop test environment as well as test cases. The engine model is used for pre-calibration of open Loop maps (EGR, THR, WG and SOI) as well as for control model identification and calibration on 12 working points of operation. Typical control parameters for feed-forward, feedback and anti-windup-functions.
For the functional a model-based test environment has been set up, including a sophisticated engine model provided by VOLVO, which is then operated in closed loop simulation with the controller. As control variables the air mass flow model value (MfAirMdld) and the intake manifold pressure (P2) or alternative exhaust manifold pressure (P3) were used, actuators are EGR and Wastegate (WG) valve.
For the air mass model, a Recurrent Neural Networks (RNN) and Long Short-Term Memory (LSTM) was used. The main advantage of the recurrent model over a (static) feed forward Neuronal Network Model is that the dynamic can be much better modelled which lead to a significant lower model error.
An Average Model Fit of NRMSE: 91.81% on Test Data (datasets tested separately) and an error lower than 5% for the range of ±3σ could be reached.



Impact / what's next:

The Multivariable control concept is proofed to support the combination of lean sensor concept, low calculation effort, fast application and high accuracy. The solution is extended by the application of data driven models for the air path using machine learning technology.
While the controller kernel is already validated in engine testbed and vehicle application, the further use of artificial intelligence as a fast and robust is a topic for further research.

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