Artificial Intelligence Based Calibration and Predictive Control for Future Engines

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Outline

• Introduction
• Research Facility and Methodology
• Results and Discussion
• Future Outlook
• Conclusion
Future vehicles/engines on the way

Artificial intelligent and unmanned control!
Wearing the Google goggles or using a Google driveless car?
Research Facilities

Design of control strategy

SIMULINK

Rapid Control Prototyping (RCP)
Research Facilities

Transient Test Bench

AVL Transient Testing Bed (PUMA), -20°C
Research Methodology

Controller Development

Control Algorithm

Offline Test

Online Test

Hardware In the Loop Test System

Control-oriented Vehicle Engine Model

23/08/2018
Research Methodology
Research Methodology

- Strength Pareto Evolutionary Algorithm 2 (SPEA2)
- Chaos-enhanced Accelerated Particle Swarm Optimization (CAPSO)

Artificial Intelligence: Intellectualizing the Future

- Fuzzy Logic Controller (FLC)
- Fuzzy clustering
- Model Predictive Control (MPC)
- Model-free Predictive Control (MFPC)

Evolutionary Algorithm

- Intelligent Engine calibration
- Intelligent Component Sizing
- Top Level Online Intelligent Control

Application

- Lower Level System Control
- Electric Motor Control
- Driver Model for Front-forward Vehicle Simulation Platform
- Clustering and Classification
- Model-Free Predictive Control
- Complex System Modelling
- Driver Behavior Prediction
- Advanced Model Predictive Control
Calibration Methods

- Calibration with Evolutionary Algorithm


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Calibration Methods

- Transient Calibration with Chaos-enhanced Accelerated Particle Swarm Optimization Algorithm

Control Methods

- Self-adaptive Fuzzy Logic Control (FLC)

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The rule in column 4 and row:
IF $X_1$ is Zero, AND $X_2$ is Negative Medium, THEN PI output = Positive Small.
Control Methods

- Model Predictive Control (MPC)

Results and discussion

- Model-based Computational Intelligence Multi-objective Optimization for GDI Engine Calibration

Results and discussion

• Computational Intelligence Non-model-based Calibration Approach (CINCA)

Convergence of particles after 50 loops of iteration
(1500 rpm / 8.3 bar BMEP)


BSFC 3.1% ↓
PMn 6.8% ↓
PMm 6.9% ↓
Results and discussion

- Intelligent Air/Fuel Ratio Control Strategy with a PI-like Fuzzy Knowledge Based Controller for GDI Engines

Results and discussion

- Intelligent Transient Calibration of a Dual-loop EGR Diesel Engine using Chaos-enhanced Accelerated Particle Swarm Optimization Algorithm

Results and discussion

- Tuneable model predictive control of a turbocharged diesel engine with dual loop exhaust gas recirculation

Results and discussion

1) MPC makes more use of LPEGR instead of HPEGR than the PID controller
2) Less EGR overshoot. Produces more torque for the same fuel delivery
3) More energy through turbo because less HPEGR use – more efficient
Results and discussion

- Tuneable model predictive control of a turbocharged diesel engine with dual loop exhaust gas recirculation

The mechanism of the BSFC reduction via the MPC-based controller is the improved VGT efficiency. Compare with the PI controller, the MPC-based controller achieves better performance on regulating the H/LPEGR fractions, while keeping the total EGR rate as the target value.
Intelligent Sizing of for the Hybrid Engine

- An algorithm for hybrid electric powertrain intelligent sizing is developed.
- The proposed CAPSO algorithm is capable of finding the real optimal result with much higher reputation.
- The CAPSO gave more reliable results and increased the efficiency by 1.71%.

Zhou Q., Zhang Y., Li Z., Li J, Xu H.*, Oluremi O., Cyber-Physical Energy-Saving Control for Hybrid Aircraft-Towing Tractor based on Online Swarm Intelligent Programming, IEEE Transactions on Industrial Informatics, 2018,
Energy Management for Hybrid

- The OSIP can optimize the vehicle performance in real-time with a maximum **prediction horizon size of 35s**.
- The vehicle with OSIP outperforms the system without it in energy saving at all initial battery SoC level.
- The proposed energy management method is robust and reliable, and up to **17% fuel and 13% total energy saving**.

Modelling of energy-flow

Controller framework

Target vehicle

Zhou Q., Zhang Y., Li Z., Li J., Xu H.*, Oluremi O., Cyber-Physical Energy-Saving Control for Hybrid Aircraft-Towing Tractor based on Online Swarm Intelligent Programming, IEEE Transactions on Industrial Informatics, 2018,
Outlook

**Mastering the game of Go without human knowledge**


A long-standing goal of artificial intelligence is an algorithm that learns, in a self-sustaining fashion, to solve games such as chess or Go at superhuman proficiency in challenging domains. Recently, AlphaGo became the first program to defeat a world champion in the game of Go. The core of AlphaGo is a neural network that plays 15 moves ahead against a fixed opponent. This neural network is trained by supervised learning from human expert games, and by reinforcement learning from self-play. Here we introduce an algorithm that solves the game of Go in self-play, without human data, and with domain knowledge. The algorithm learns from self-play by extending the tree search of AlphaZero, a neural network trained on the history of moves played in self-play. The result is a system that can learn to play Go at superhuman levels, and that can be trained to play any game of Go at any level, from self-play to human expert, in just a few days. The system is trained on games played by a self-play system, using the same architecture as AlphaZero, but with a larger dataset and more sophisticated training. The system outperforms other existing systems on a range of games, including chess, Go, and Shogi, and is the first to achieve superhuman levels of performance on all three domains. The system is also able to learn to play any game of Go at any level, from self-play to human expert, in just a few days. The system is a model-free, predictive, and scaleable approach to machine learning, and it can be applied to a wide range of domains, including computer vision, natural language processing, and robotics.
Summary & Conclusion

• The development of Artificial Intelligence technology has provided a new horizon for the design and operation of future combustion engines. Further improvement and optimization of the engine system will be possible beyond the conventional present possibilities.

• Engine calibration will transit from human knowledge-based methods to AI based methods, which can resolve much more complex problems involving multi-variables and multi-objectives in much shorter time and at lower cost.

• Predictive optimal engine control will come into application, from the linear-model-based to nonlinear-model-based and finally to model-free predictive control with machine learning capability.
Publications


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