Accelerated progress

Modern IT processes can accelerate the development of innovative energy converters and complete powertrains. With this in mind, researchers working on FVV projects are investigating the applicability of innovative methods such as object-oriented architectures and machine learning.

Managing variant diversity //

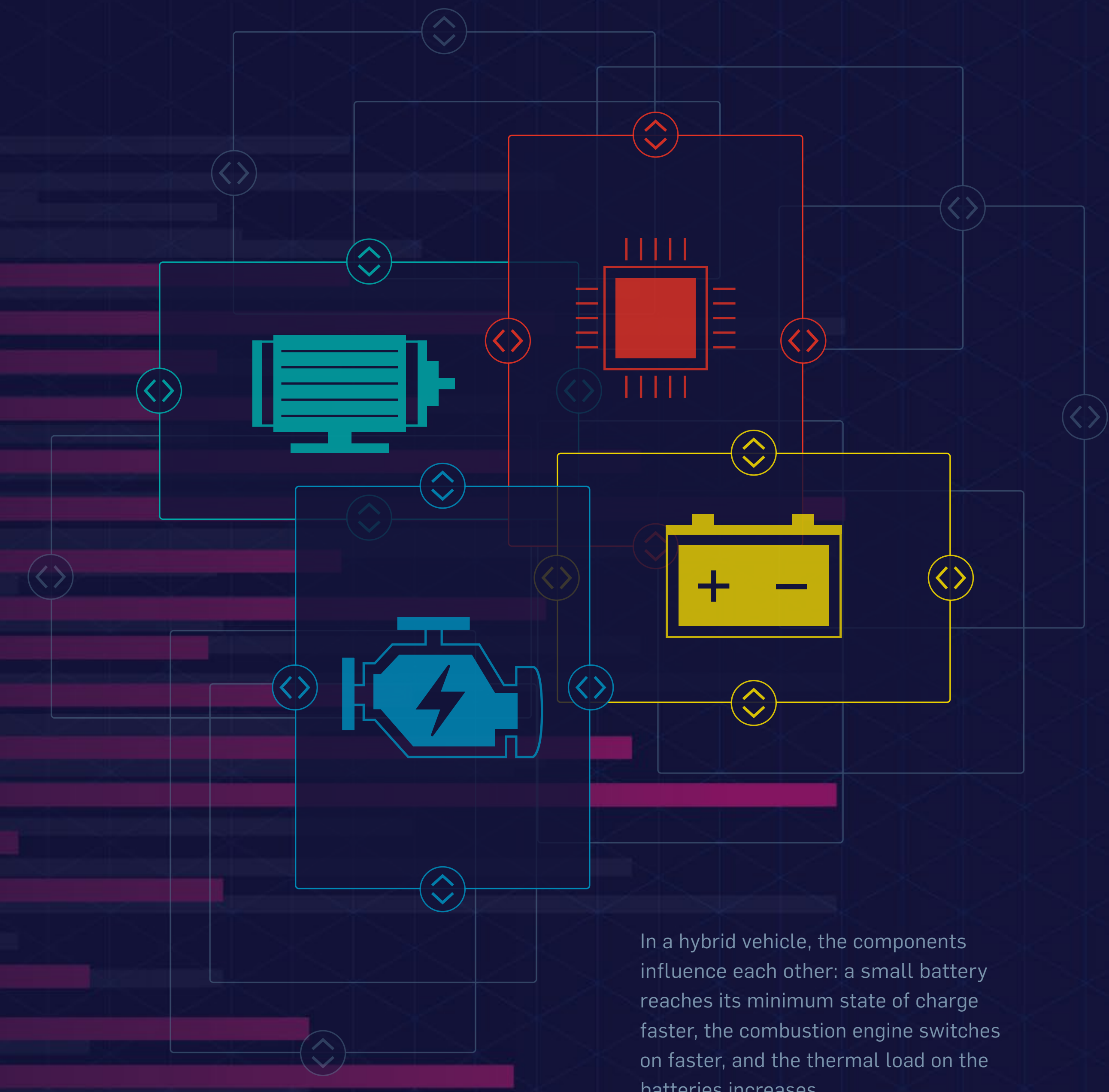
The development of hybrid powertrains presents engineers with huge challenges. Complex architectures, different powertrains, multiple energy conversion processes, interactions between subsystems and the interdependence of components increase complexity. And variant diversity is set to rise further in future, as it will be possible to combine various combustion engines, batteries and electric motors. Taking all of this into account during development requires an increased degree of modularity and an object-oriented architecture.

In FVV's ›Modular Hybrid Powertrain‹ project, researchers from the Technical University of Darmstadt are developing an integrated approach to efficiently meet different market requirements. In the concept phase, it is a question of finding a database for object-oriented designs and transferring this to modular structures for hybrid powertrain systems and the individual powertrain components. »You can picture this as a computer, where individual components such as the mouse, monitor, keyboard and printer form a complete system. Each component is an object that is networked and communicates with the others,« explains Prof. Dr. Christian Beidl, head of the Institute for Internal Combustion Engines and Powertrain Systems (VKM) at the Technical University of Darmstadt.

Transferred to a hybrid vehicle, the principle can be represented by a traction battery, for example. Its capacity has a decisive influence on the operating strategy of the vehicle. A small battery will reach the minimum charge level faster, the combustion engine will kick in earlier and the thermal load of the battery will increase. In a nutshell, the load profile will be completely different to that of a larger battery. In the object-oriented architecture, the researchers need to consider electrical, mechanical and software-based properties and dependencies. This requires further standardisation of the interfaces, which will provide great flexibility when it comes to adding, removing and scaling components.

Text: Matthias Heerwagen

Object-oriented architectures in powertrain development



In a hybrid vehicle, the components influence each other: a small battery reaches its minimum state of charge faster, the combustion engine switches on faster, and the thermal load on the batteries increases.

Thus, an object-oriented architecture takes into account the electrical, mechanical and software-based properties and correlations.

From FVV's perspective, the advantage of an object-oriented component definition is that it will also improve opportunities for suppliers in terms of how they interact with OEMs. »If we are working with a common description basis, every supplier will know what properties the component has to have. And every integrator will then be able to integrate this component,« explains Professor Beidl. The investigations will be based on the VKM's existing simulation structures, which already have a flexible and modular design. Two sample hybrid configurations are being used to validate the devised approach and the team is devising a matrix for evaluating the suitability of architectures.

Another project is also dealing with the challenge of growing variant diversity, as the number of parameters is also increasing in classic engine development. Stroke/bore, valve control, charging strategy or number of cylinders – every detail can vary and each change results in a completely different engine design. During the basic design of a new engine, the zero- or one-dimensional simulation is an indispensable development tool.

»The advantage of these methods is that they have relatively short computing times. However, here too, multi-dimensional optimisation problems in the calculation can be very time-consuming,« explains Dr. Christian Schnapp, development engineer at Toyota Gazoo Racing Europe. This takes up valuable time that could be spent elsewhere in the development phase. In the Heuristic Search and Deep Learning research project, Schnapp and his colleagues from the Chair of Thermodynamics of Mobile Energy Conversion Systems at RWTH Aachen University and the Institute of Automotive Engineering at the University of Stuttgart are looking for ways to reduce the computing time. This special project aims to simulate the high-pressure curve in the combustion chamber.

»We want to investigate how artificial intelligence can help in the development process by mapping the simulation via neural networks. We are pursuing two approaches to do this,« explains project coordinator Schnapp. In the first approach, deep learning is used and, as a first step, requires the researchers to generate many millions of data sets with a detailed model that they will then use to train a neural network – a form of artificial intelligence. The AI algorithm is based on libraries that are freely accessible in the Python programming language and that the engineers can make use of. »This is a common standard and means that other researchers or companies can also use the algorithm,« says Schnapp.

Sample projects on
FVV's research priority ›Digitalisation‹

→ » Modular Hybrid Powertrain [1428]« // **FUNDING:** FVV // **PROJECT MANAGEMENT:** Dr. Veit Held (Stellantis Opel Automobile) // **RTD PERFORMER:** Institute for Internal Combustion Engines and Powertrain Systems (vkm), TU Darmstadt

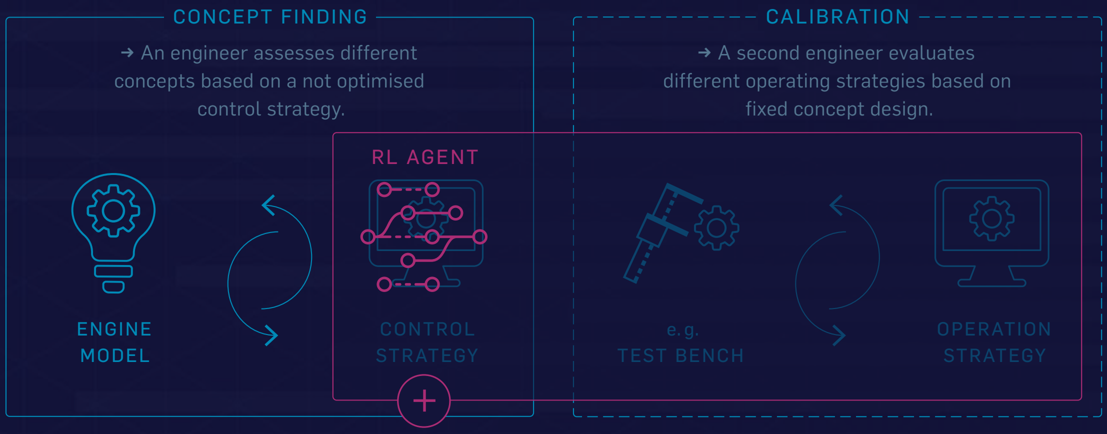
→ » Heuristic Search and Deep Learning [1426]« // **FUNDING:** BMWK/AiF (21407 N) // **PROJECT MANAGEMENT:** Dr. Christian Schnapp (TOYOTA GAZOO Racing Europe) // **RTD PERFORMERS:** Teaching and Research Area Mechatronics in Mobile Propulsion (MMP), RWTH Aachen University / Chair of Thermodynamics of Mobile Energy Conversion Systems (tme), RWTH Aachen University / Institute of Automotive Engineering (IFS), University of Stuttgart

The initial data is impressive: the AI produces a result 50 times faster, and without jeopardising accuracy. The models can therefore be integrated into real-time applications in future or even used to solve higher-dimensional optimisation problems – for example, if several components in the overall system need to be optimised.

The other approach concerns what is known as reinforcement learning. So far, a simulation engineer has been working in the development phase and studying various engine concepts which do not yet have an optimum control strategy. Another engineer then develops this strategy on the test bench. The idea is then to hand this task – whether it be the control of an e-booster, waste gate or the setting of the ignition time, for example – over to a reinforcement learning agent. »By carrying out lots of simulations, the agent attempts to teach itself the best control strategy,« explains Schnapp, who adds: »This is performed by rewarding the agent for a success, so that it always learns more.« A time-consuming undertaking it may be, but the calculation time can be shortened by running parallel simulations. It is conceivable that the trained strategy will be implemented directly into the ECU in the future.

The project is set to run until 30 April 2023, but FVV members will soon be able to benefit from the initial results and rapid knowledge transfer: »There is certainly interest in the code, so we are going to hold a workshop in which the code from the first work package will be made available,« says Schnapp. The final documentation and a simulation tool for immediate use will be provided at the end of the project. //

Reinforcement learning for the concept design of SI engines



→ Today's ENGINE DEVELOPMENT PROCESS consists of two distinct steps. This approach leads to suboptimal layouts, because the transient engine behaviour should already be taken into account during the concept finding phase.

→ A reinforcement learning agent finds the optimal control strategy for each engine design. By integrating the RL AGENT into the concept finding process, an appropriate evaluation of a control strategy can already be carried out in the first step.