Artificial intelligence propels powertrain development

- A powertrain is the system that propels any energy-demanding machine.
- All industries developing engines, including the automotive, marine and aviation industries, and energy producers, use powertrains.
- The range of potential powertrain concepts has led to a huge increase in manufactures' development costs.
- Artificial intelligence (AI) can help to make the development process leaner and more efficient, thereby reducing costs.
- In his book, *Powertrain Development with Artificial Intelligence,* Dr Aras Mirfendreski explains AI concepts and clarifies their use with powertrain applications.

A powertrain is the system inside any energy-demanding machine that propels it, such as ships, airplanes, and electricity generators. In a car, the power is created by the engine and delivered to the wheels. A powertrain's key components include the engine, transmission, differential, driveshaft, and axles. The array of potential powertrain concepts has led to a huge increase in manufactures' development costs, but fortunately artificial intelligence (AI), data analytics, and big data are now available for a leaner and more efficient development process. To employ them, however, developers need to know what AI really means. What concepts underpin it? Moreover, how can these methods and algorithms be transferred to powertrain applications?

These questions are answered by Dr Aras Mirfendreski, CTO at Aquarius Engines, in his book *Powertrain Development with Artificial Intelligence* published by Springer in 2022. Bridging the gap between computer science and automotive engineering, he explains AI concepts and clarifies them for use with powertrain applications. Mirfendreski elaborates on work processes, demonstrates how AI can be applied, and reveals how these innovative methods can help us change what's in store for energy and mobility.

The drive for optimisation

The modernisation of technologies during the agricultural and industrial revolutions brought with it the development of driving concepts powered by steam, electricity, and combustion. Greater efficiency and enhanced driving range, together with the creation of a network of filling stations, supported the internal combustion engine over its competitors in the race to supply mobility to the masses.

Combustion engines are already achieving low CO_2 emissions and further optimisation efforts have brought only marginal improvements at similar or greater investment. Investment trends cannot continue as they are, and they will only become profitable with the implementation of more efficient, lean development processes which will lead to cost reduction. Mirfendreski describes how AI concepts offer versatility, reliability, and high efficiency, and presents ways to transfer digital IT concepts and methods to manufacturing.

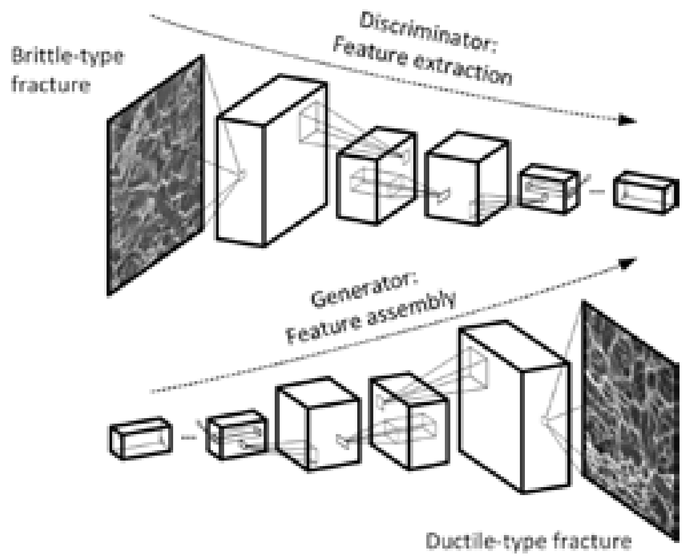
Simulation, big data, and AI

Simulation has been employed as a development tool since the 1970s. Using simulation tools throughout the development phases of powertrains offers possibilities that could not be applied with such speed if developers were to use a test-based approach. Furthermore, simulation avoids the production of physical prototypes, therefore saving on hardware costs.

In addition to the technological progress in handling large amounts of data, big data brings advances in development methods. While huge indefinable amounts of data can be generated and stored, the systematic handling of these data still poses a significant challenge.

AI-based concepts offer several advantages for the development of powertrains. Unlike conventional computing systems, artificial intelligence aims to adapt human thinking, learning, and decision-making into mathematical models. Uniquely, AI systems can undergo a machine learning process and adapt to recurring problems. AI modelling can also integrate calculations and methodologies into existing development processes, thus offering a significant increase in development speed, together with a more efficient and leaner development process. AI-based development is particularly suitable for lifecycle modelling, which covers the progression of a product from its initial design and simulation to integration, testing, monitoring, and maintenance.

Mirfendreski demonstrates how AI can be applied and reveals how these innovative methods can help us change what's in store for mobility.



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Functioning of the discriminator (top) and the generator (bottom) at microscopic fracture structures of a metal material.

This book is a resource both for engineers interested in how AI can benefit drive development, and for IT specialists and AI users who want to find out more about industrial applications of their methods.

Learning from data

Machine learning, a subcategory of AI, uses big data to help systems to learn from data. Machine learning can be divided into three main learning categories: supervised learning, unsupervised learning, and reinforcement learning.

In supervised learning, input and output data is provided to the system. Labelled datasets are used to train algorithms to classify data, predict outputs, and improve the model fit to the known outcome. Machine learning algorithms are normally used to examine and group unlabelled datasets. In his book, Mirfendreski shows how supervised learning can be applied to powertrains for determining the characteristics of engine flow and combustion, or the battery health management of electric engines.

In comparison, unsupervised learning algorithms uncover unknown patterns in the data. As a result, the system can characterise hidden features within the data without needing human input. Example applications of unsupervised learning in the book include increasing fuel cell efficiency and analysing material load.

Finally, reinforcement learning is characterised by its high performance and self-learning properties. It uses an AI-driven system, known as an agent, to learn through trial and error. The agent uses both negative and positive feedback from its actions, signalled as 'punishment' or 'reward', and aims to maximise the reward function.

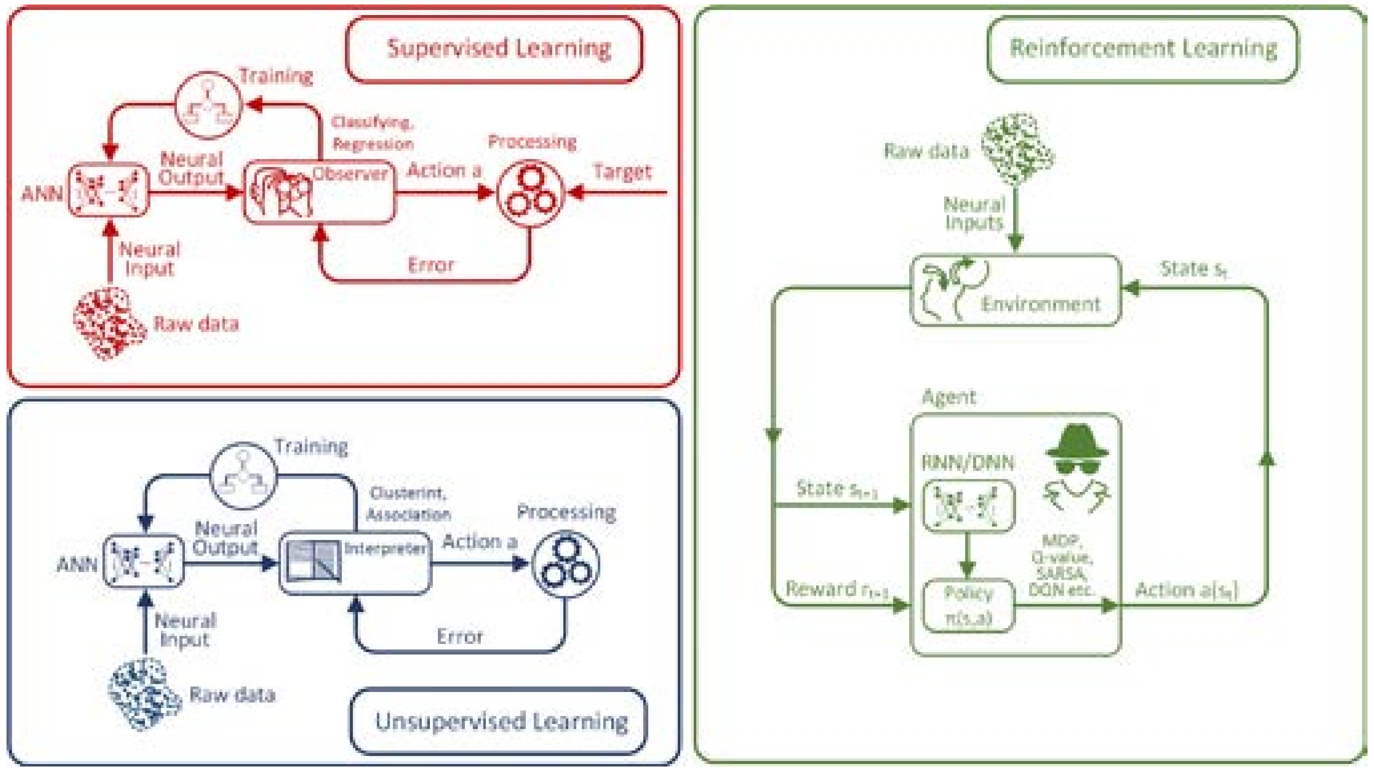
Reinforcement learning essentially imitates natural intelligence and learns from its mistakes. Mirfendreski demonstrates the use of reinforcement learning adaptive speed controllers and vehicle chassis design examples.

Artificial neural networks

Artificial neural networks (ANN) attempt to simulate a human brain, aiming to learn and make decisions in a humanlike manner. Artificial neural networks behave as though they are interconnected brain cells. The neural network architecture is made up of many computational processes running in parallel. The overall process is divided into many small parts. Each unit in the network performs a part of the process. It receives inputs from external sources or other neighbouring units, calculates a new output value, and then passes the information on to other units. The book includes an example application of ANNs in predicting emissions from the real driving emission (RDE) cycle. Car emissions are measured on trips known as RDE cycles with requirements specified by the EU. These include route conditions, distance, speed, duration, and trip dynamics to ensure that cars deliver low emissions over on-road conditions.

A concept book

Mirfendreski explains how this book is intended as a concept book, consolidating possible uses of AI in industrial applications. It presents complex AI topics and creative conceptual ideas and applies them to powertrain development. This harnessing of AI is relevant to all engine concepts, not just automotive combustion engines. It can also benefit developers of fuel cell engines, electric engines, alternative ICE fuel types, and sectors such as generators, CHP-market, outboat industry, aviation, marine, and telecommunications. He hopes that it encourages readers to be creative, leaving old methods behind and forging their way towards new methods. This book is a resource both for engineers interested in how AI can benefit drive development, and for IT specialists and AI users who want to find out more about industrial applications of their methods.



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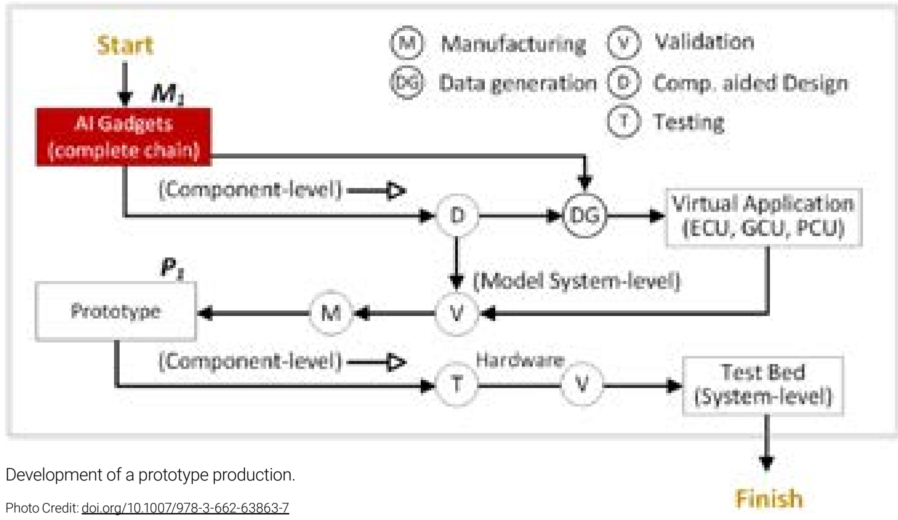

Development of a prototype production.

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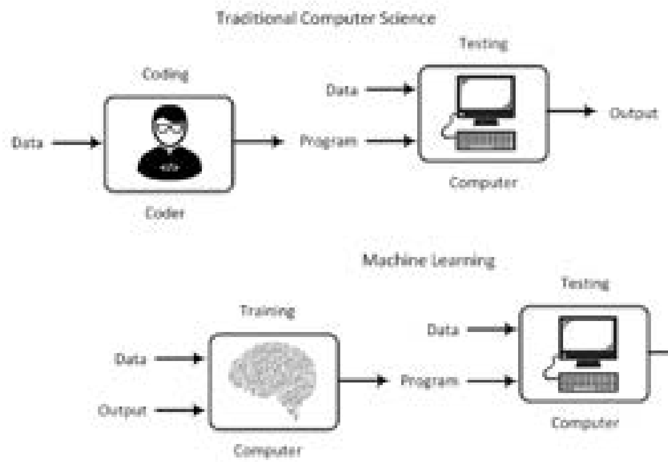

Traditional programming versus machine learning.

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Personal response

What initially sparked your interest in powertrain development?

Engines require multidisciplinary knowledge and cover almost all scientific aspects of physics. They are among the most complex systems developed by humans, and I had always been interested in understanding this complexity. During the world's largest energy transformation and alternative propulsion concepts and fuel variants, even more exciting aspects are being added. So many interesting aspects of development await us engineers and scientists and developers, and I consider myself privileged to be able to contribute to this.

What does a typical day as CTO at Aquarius Engines entail?

The far-sightedness of the company's positioning in the technological sense and the development of technological strategies to get there are among the major challenges of my role. The important thing is to always be well-informed and to crystallise out of the many interesting and new strategic paths the ones that are most feasible in the context of all the parameters relevant to the company.

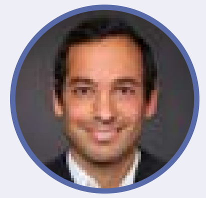
What has been the most satisfying aspect of this research?

Creativity. Marrying industry and IT sciences, building a crucial bridge, developing thought-provoking ideas in both directions and communicating them to readers has enriched me personally.

What are your plans to extend your research into powertrain development with artificial intelligence?

There is certainly a lot of work ahead of us in this direction. With my book, a first stone has been laid and I hope that many developers will pick up my basic conceptual ideas and develop them further with much deeper details. I personally don't have any further plans in this regard for the time being, but there will certainly be new concept books to be expected by me.

Details



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Springer link [English version]: Powertrain Development with Artificial Intelligence: History, Work Processes, Concepts, Methods and Application Examples | SpringerLink

Springer link [German version]: Künstliche Intelligenz für die Entwicklung von Antrieben: Historie, Arbeitsprozesse, Konzepte, Methoden und Anwendungsbeispiele | SpringerLink

Collaborators

Springer

Bio

Dr Aras Mirfendreski completed his doctorate at Audi AG. He gained experience as a powertrain developer for various OEMs at the Research Institute of Automotive Engineering and Vehicle Engines Stuttgart and worked as a senior program manager at Toyota. Currently, he serves as CTO at Aquarius Engines in Germany. Mirfendreski is also an AI expert, keynote speaker and consultant around many technological topics.

Further reading

Mirfendreski, A, (2022) *Powertrain Development with Artificial Intelligence*, Springer-Verlag GmbH Germany. doi.org/10.1007/978-3-662-63863-7

Mirfendreski, A, (2022) *Künstliche Intelligenz für die Entwicklung von Antrieben*, Springer-Verlag GmbH Germany. doi.org/10.1007/978-3-662-63495-0