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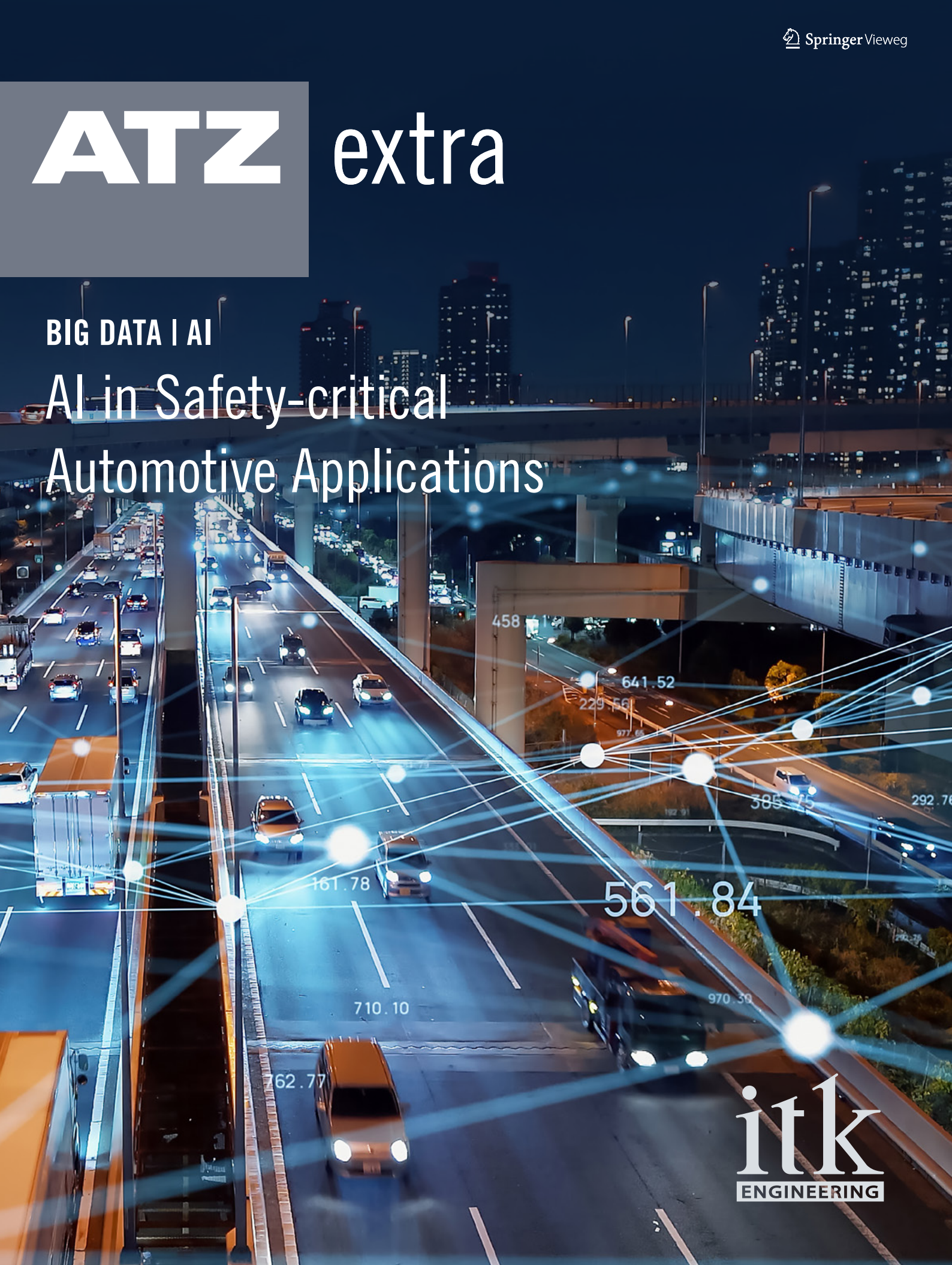
AI in Safety-critical Automotive Applications



itk ENGINEERING

AI in Safety-critical Automotive Applications

Artificial Intelligence (AI) is taking the development of vehicles and their functions to a new level. ITK Engineering is dedicated to the question of which analysis methods and systematic approaches can be used to ensure the necessary safety aspects of machine learning systems to comply with ISO PAS 8800.

Rapid advances in artificial intelligence are affording engineers myriad opportunities to develop innovative automotive features. The downside of these advances is that they put automakers under tremendous pressure to innovate. Accidents involving automated vehicles are another issue [1]. What's more, governments are rushing to regulate AI [2]. All this gives rise to a key question: What could a standardized approach to developing safety-relevant AI systems in vehicles look like? The ISO PAS 8800 specification is going to furnish this framework for developing these systems in vehicles. This standard will guide manufacturers and suppliers that develop AI systems for automotive functions [3].

THE CHALLENGES OF DELIVERING SAFE AI SYSTEMS

AI systems typically serve to solve challenging problems. In vehicles, they primarily enable automated driving functions. Deep learning systems are crucial to this end. They use algorithms to analyze vast quantities of data to learn complex tasks, for instance, how to recognize objects. This transpires in the open world, so engineers have to find a way to continuously develop and assess the safety of AI systems in the vehicle. Another challenge to consider is the very nature of AI-driven methods. For one, deep neural networks are nonlinear and exceedingly complex, which makes them difficult to comprehend and explain. For the other, their limited generalization ability and robustness narrows their functional range. Data-centered tasks such as collection, annotation, and dataset design merit special consideration because the behavior of AI models based on Machine Learning (ML) is implicitly specified and determined by the data used.

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SAFETY ARGUMENTATION FOR AI SYSTEMS

Constructing an argumentation, referred to as ‚assurance argument' to substantiate the product's safety is integral to every safety standards-compliant development project. In this context, "safety" means that the chances of personal injury attributable to a system malfunction or to reasonably foreseeable misuse has been reduced to an acceptable level of risk. The assurance argument has to be structured systematically [4]. Engineers can render it schematically using Goal Structuring Notation (GSN).

An assurance argument for an AI system certainly has to address the specific challenges posed by AI. The first step is to consider the safety requirements determined for the AI system, the AI's relationship with the overall system, and the input space. This input space describes the AI system's possible input values and is related to the Operational Design Domain (ODD). An AI system can only be audited for potential functional insufficiencies within the open-world context if the ODD specification goes into adequate detail [5]. The AI system's ability to operate in the input space has to be demonstrated qualitatively and quantitatively. This requires systematic analyses as well as statistical assessments, for example, to determine the probability of events occurring. The greater the input space's dimensions, the harder it is to achieve sufficient coverage. Engineers have to choose the right approach for each project. Not only the many standard scenarios have to be demonstrably 'covered, but also rare but critical situations. And the probability that unknown conditions could trigger functional deficiencies has to be low (see ISO 21448).

AI SAFETY LIFECYCLE

Engineers tasked to develop an AI system have to model its safety-relevant activities in the context of the overall system. To this end, they create an AI safety lifecycle as set out in [3].

The example of an AI safety lifecycle depicted in **FIGURE 1** shows all tasks necessary to help assert and sustain the assurance argument. As a rule, engineers deduce the safety requirements for the AI system from the encompassing system requirements. These requirements provide the input for developing, verifying, and validating the AI system. Datasets used to develop ML-based AI systems are usually generated on the fly as the AI component's iterative implementation progresses. Often, the right algorithm and methods for the given AI requirements do not begin to emerge until development is underway. This is why continuous and iterative safety analyses are imperative when developing AI systems. Usually, it is not possible to guarantee that an up-and-running AI system will always behave correctly. This is down to the ODD, which is highly complex with a status that varies over time, and to the nature of AI systems. And that is why an AI system has to be monitored and audited continuously. This process of substantiating the assurance argument's perpetual validity is called continuous assurance. If the argument is found to be invalid, engineers have to take remedial action by adapting the AI system, changing its requirements, or taking measures at a higher system level to re-establish its validity.

DATA LIFECYCLE

The behavior of ML-based AI systems is largely determined by the properties of the data used during development. These change during development and throughout the product lifecycle as new knowledge emerges and the environment changes. Requirements for a data lifecycle are a prudent way of assuring that current and consistent data is used to develop the AI. [3] Then the data

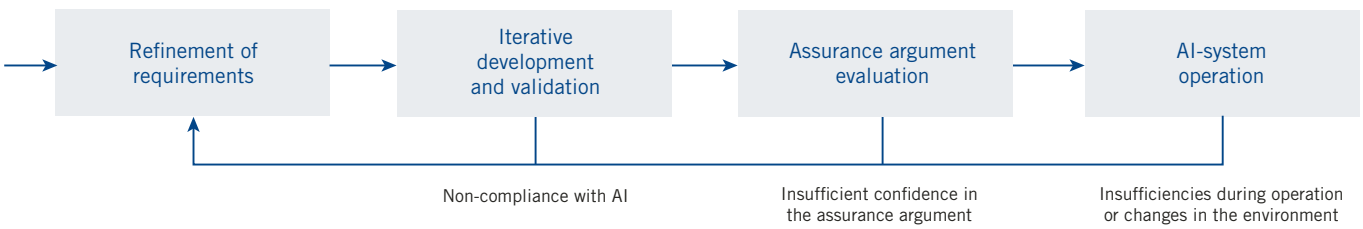

FIGURE 1 An example of an AI safety lifecycle – modified representation in line with [3] (© ITK Engineering GmbH)

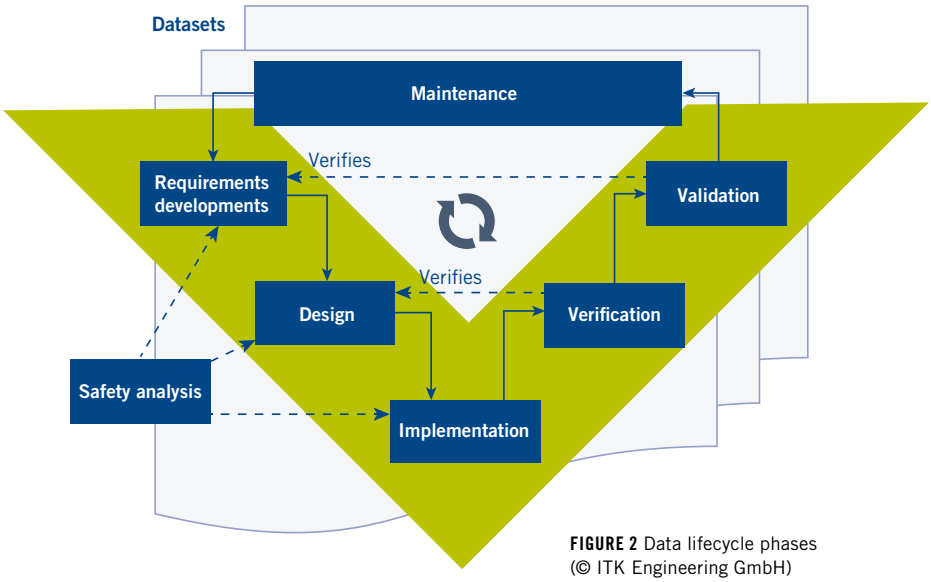

FIGURE 2 Data lifecycle phases (© ITK Engineering GmbH)

lifecycle can provide a basis for constructing a valid assurance argument.

The data lifecycle depicted in **FIGURE 2** typically begins with a data safety analysis. This aims to identify potential safety-relevant deficiencies, develop countermeasures, and define metrics for assessing preventive actions. The identified insufficiencies, root causes, and effects serve as the input for the subsequent phases, dataset requirements development, dataset design, and dataset implementation.

Dataset requirements development is all about formulating the specifications for the dataset and subsequently deducing the quality assurance requirements. This is done under the assumption that the methods set out in ISO 26262-3 for the item definition and ISO 21448 section 7 for the triggering conditions have been followed.

These requirements furnish the foundation for the next phase, dataset design, which revolves around the task of building the dataset. This entails compiling data from physical, synthetic, [6] or augmented data, preprocessing data, and dealing with metadata. Engineers then shall make their preparations, define annotation processes and methods, and carry out the actual annotation during the dataset implementation phase. Next up is dataset verification, which goes to ensure datasets are consistent, correct, and in line with the given requirements. Dataset validation serves to confirm that datasets satisfy the extrapolated requirements and meet expectations. Maintenance means keeping the working datasets up to date and in compliance.

DETERMINING AI REQUIREMENTS

Engineers are supposed to deduce the requirements for an AI system from the overall system's requirements, but these specifications are usually not quite specific enough to define direct measures to be taken in case of noncompliance.

To minimize risks during the AI development effort, it is advisable to define the influencing factors that will enable engineers to set out qualitative requirements. One way to get started is to consider the safety concerns mentioned in [7].

Some of these are measurable properties of the trained AI model, the data, or the development processes. Robustness, generalizability, explainability, and the like can be quantified, so they provide the metrics for refining AI safety requirements.

This is done by conducting a safety analysis to identify and assess properties that are maximally correlated with the violation of an AI requirement. Many of these properties can be determined directly or by way of correlated measurements. It is up to engineers to decide which of the various methods available for the given application and model are best suited for the use case. This assessment provides the insights they need to come up with specific measures to address the development or architecture of the AI system.

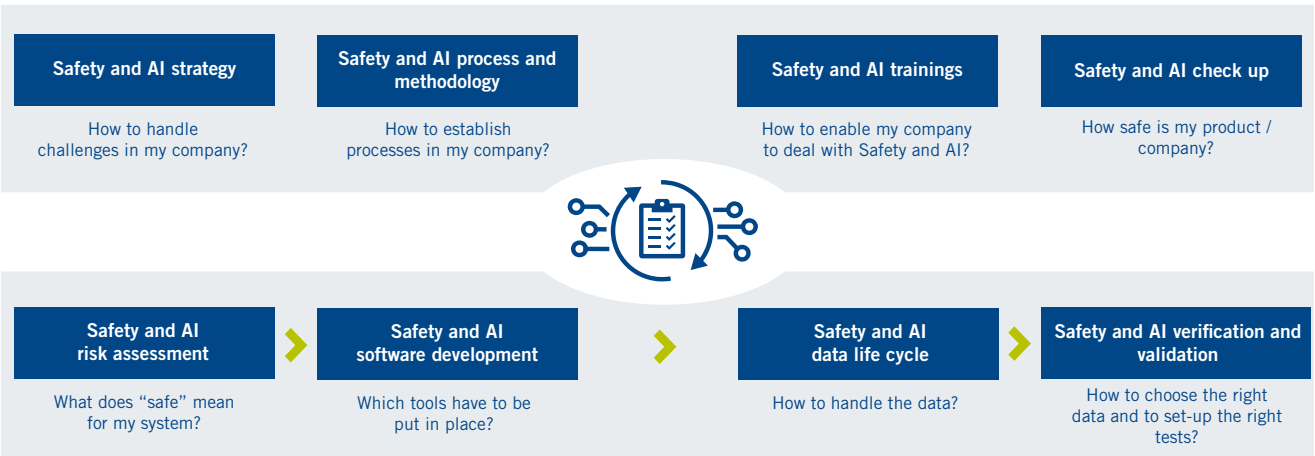

FIGURE 3 Safety and AI-specific challenges (© ITK Engineering GmbH)

CONCLUSION AND OUTLOOK

Emerging standards and specifications such as ISO PAS 8800 will certainly have an impact on the state of the art in automotive safety and AI. Engineers will need to meet certain requirements and follow specific processes for AI and data lifecycles to accommodate changes in safety requirements over time and after the start of production.

Data is integral to ML systems' training. It is even replacing some of the specifications and requirements, prompting the observation that data are the new requirements. This is why a systematic approach in form of a data lifecycle is sure to figure prominently in the future.Engineers have to get a holistic picture of safety aspects and factor the specificities of AI methods into the equation. To this end, they need additional safety analytics such as GSN and STPA.

Future safety and AI audits and assessments are going to pose a major challenge. Safety experts will have to add AI to their skill-sets – otherwise, outside AI experts will have to be brought in to provide support.

What's more, continuous development and continuous assurance represent a paradigm shift in safety engineering, so there is little experience to fall back on. In this respect, AI is both a blessing and a curse for safety-related automotive applications. On the one hand, AI can provide powerful solutions to problems such as environment recognition. On the other, developing and operating safe AI systems is a journey fraught with towering challenges.

A deep well of knowledge of specialists in safety, AI, and verification and validation creates precisely the skill-set needed to rise to safety and AI-specific challenges and solve emerging problems, **FIGURE 3**.

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