Siemens Digital Industries Software

From chip to city: exploring AI's influence on the future of autonomous mobility

Digital Industries Software

Executive summary

Automotive, technology and 5G telecommunications companies are teaming together with cities to define the next generation of autonomous mobility. The interactions between these complex environments will challenge and inspire engineering innovation. Artificial intelligence (AI) is a critical thread that ties these communities together to efficiently create new solutions that are smart, connected and that can sense, automate and predict in ways that were hard to imagine only a decade ago. This is where today meets tomorrow for autonomous vehicles.

Gabriele Pulini, Product marketing manager
Matthieu Worm, Director autonomous vehicles
Siemens Digital Industries Software

Introduction

To help build the future of mobility, Siemens provides the comprehensive digital twin, a virtual representation of a multi-domain physical product or process that is used to understand and predict the physical counterpart's performance characteristics. A digital twin that incorporates all aspects of the product – mechanical, electrical and software – complements AI throughout the product lifecycle to simulate, predict and optimize the product and production system to minimize the need for physical prototypes and assets.

By incorporating multi-physics simulation, data analytics and AI capabilities, a comprehensive digital twin is able to demonstrate the impact of design changes, usage scenarios, environmental conditions and numerous other variables. This drives down costs, reduces development time and improves the quality of the final product or process.

Tools within the digital twin, infused with AI themselves, are employed to create complex systems that someday will enable autonomous vehicles that move efficiently and safely within cities. Built around the comprehensive digital twin, Siemens has created the vision of the mobility digital enterprise (figure 1).

The vision of the mobility digital enterprise consists of a holistic data infrastructure which makes data interpretable and comprehensible across individual tools. This starts with world-class chip design and verification tool flows, combined with physical sensors and actuators to form vehicle electronic systems. Transporting and interpreting data from these electronic systems to electrical cabling and wiring tools and mechanical design tools for vehicle design and simulation requires a seamless interface. The models of these systems will be used to drive the smart factory floor for manufacturing. Digital feedback through ontologies and cloud-based data analytics at each step of the way allows for changes and improvement. The vehicle of the future in use will be a rich pool of engineered and interpreted data from design and production. When moving in connected cities of the future, a new computing paradigm in smart cities will handle the data deluge and deliver real-time, intelligent data processing, analysis and decision making. Feedback from these scenarios will find its way back through the digital twin to improve the vehicle.

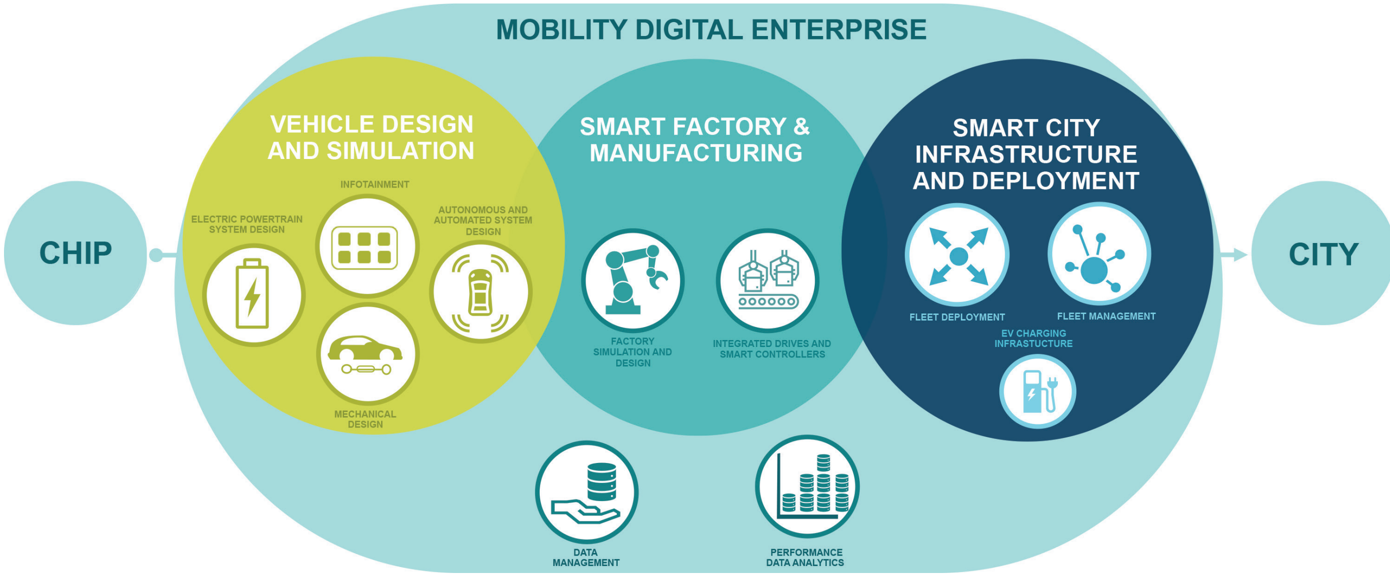

Figure 1: The mobility digital enterprise.

The heart of AI: designing and verifying the chip

As AI is continually integrated into a myriad of today's products, such as smartphones and IoT edge devices, its greatest impact could very well be on autonomous vehicles. Computer vision, sensor fusion and object recognition systems abound in these vehicles. At the center of these innovations is the AI chip.

Custom AI chips riding aboard complex electronic systems within the car have machine learning (ML) algorithms that can recognize objects on the road and make appropriate decisions. It is imperative for designers to be able to train the algorithms and generate synthetic scenarios, such as pedestrians stepping on the street. Autonomous vehicles will be able to transfer learning and consistently update their algorithms based on feedback from other vehicles experiencing varying scenarios.

But AI algorithm developers are software people who are used to writing code without the specific knowledge of hardware languages and tools used to develop chips. They tweak their algorithms many times per day. Because the AI world progresses so quickly, they need a way to design and verify an algorithm as the specifications and requirements evolve. They can't start over every time there is a change (figure 2).

AI algorithm developers address this problem by using the Catapult high-level synthesis (HLS) flow, to design and verify their C++ and then automatically generate the register transfer level (RTL) code that drives the chip design process. The chip design team can then further explore optimizations for power and performance simply by changing constraints and directives, without having to modify the C++ algorithm code. This HLS flow has the capability of reducing the entire chip design and verification process by 50 percent.

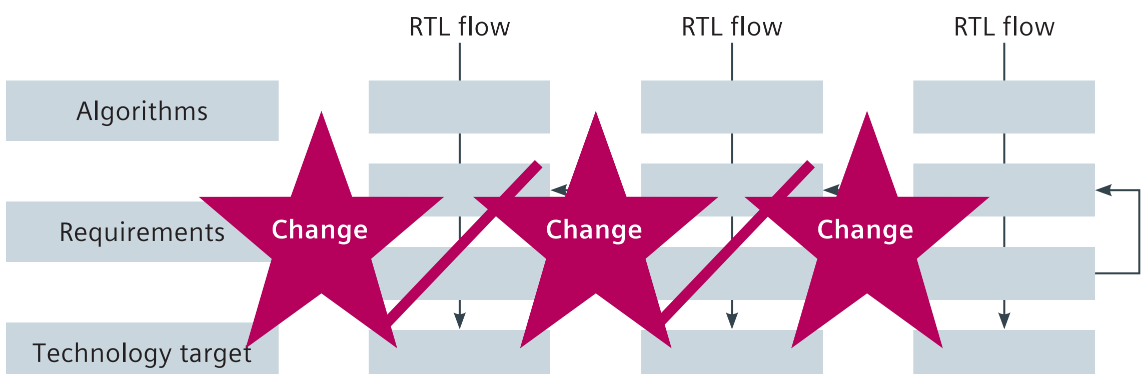

Figure 2: AI algorithms change too fast for traditional chip design flows.

Enhancing vehicle design and simulation

AI and ML can modify user interfaces based on expected tasks to increase user adoption and productivity. By changing design parameters and running AI-based algorithms, designers can evaluate possible best fits based on the results of the algorithms. They can also use data from older, existing designs to uncover latent design properties and then use these findings to improve the current model.

Generative design relies on AI algorithms to find an optimal solution by systematic variation of parameters, structure or shape of a design. The evaluation is mostly done by simulations orchestrated by space exploration tools. AI-driven behavior models for well-known parts of the system, or parts that cannot be modeled mathematically but learned instead, speed up these evaluations.

AI can recommend next steps based on predictions of the previously completed design. This supports better design quality by guiding the designer or engineer to the next logical step without having to search for the step in the menu structure. Because a comprehensive digital twin is a complete virtual representation of a physical product, speed and accuracy are key when it comes to its creation. The digital twin must represent all aspects of the system, ranging from mechanical and software model simulation to flow dynamics and electrical circuit simulations. Multiple engineering disciplines come into play in the development of digital twins and a variety of model types required to create these virtual representations.

AI technologies are beneficial to designers that build digital twin models. Machine learning can compare "learned" behavior against simulation models, helping in a myriad of ways including:

- Identifying parameter dependencies
- Calibrating the digital twin models
- Discovering issues in the simulation models themselves
- Accelerating validation and exploration of design space, including mechanical, electrical and electronic applications and multi-domain systems

On the one hand, model order reduction (MOR) models, being fast but not as accurate as standard simulation models, can speed up the learning for AI models. On the other hand, well-trained AI models can substitute the simulation models where speed and memory footprint count, such as with virtual sensors on controllers or when architectures are evaluated through generative design. Due to that acceleration, teams can explore many architectural implementations and verify the results in the same amount of time it would have taken for one original simulation run.

Simulating AI chips in the context of a vehicle

AI chips are part of an overall autonomous drive system that connects to sensors and actuators. For example, a key AI-based system in these vehicles is a system that takes in data from sensors around the car (such as a camera, LiDAR and radar) and provides input data to the AI chip. The system identifies objects and situations in real-time to make decisions. Those decisions send signals to braking and steering systems, for example. Riding on top of the hardware is the software stack (figure 3). Traditional methods of testing this chip are not adequate. What is needed is an overall solution that can simulate this system in the context of the vehicle in a virtual driving environment. Siemens Xcelerator portfolio of software includes PAVE360 that provides this solution.

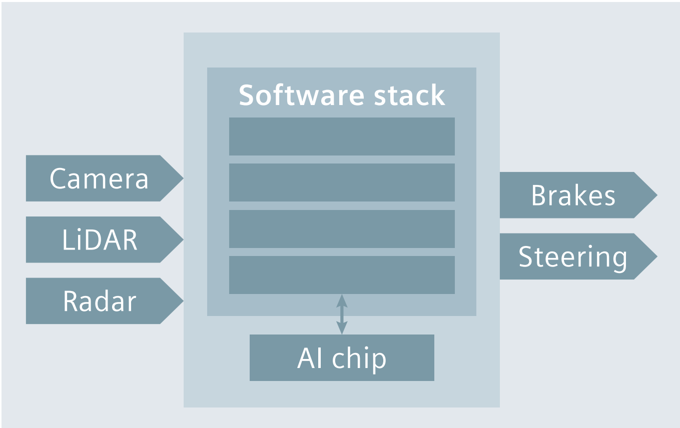

Figure 3: AI-based system for autonomous drive vehicles.

PAVE360 brings together models of the vehicle at any level of abstraction in order to simulate the AI-based system under virtual driving scenarios in order to perform safety analysis, optimizations and AI chip validation. In addition, PAVE360 can employ AI techniques to generate synthetic traffic conditions to extend testing scenarios.

Using AI in manufacturing

As vehicle manufacturers go from prototype to production, AI technology can be deployed in the manufacturing process to help achieve "first time right" production. This is especially true in the emerging area of additive manufacturing (AM) of vehicle parts. Errors originating from suboptimal scan strategies and process parameters can be addressed to drastically reduce trail-and-error time.

This technology, as seen with AM Path Optimizer, integrates AM technology with the mechanical design tool NX to solve part overheating challenges, reduce scrap and increase yield. This solution uses an innovative approach that combines physics-based simulation with ML to analyze a full job in just a few minutes before execution on the printer. Thousands of layers and millions of vectors within AM components create tremendous complexity. Therefore, a traditional finite element approach will not suffice. By training a ML algorithm on synthetic data, the simulation speeds up by a factor of 7 to 10 times.

AI on the factory floor

Digital twins are not only used to design and manufacture products, but are also a powerful way to virtualize and optimize production machinery and processes themselves. This includes material flow, resource utilization and logistics as well as robotic or factory workers' movements all the way to virtually commissioning machines. Manufacturers are producing more affordable, high-quality and customized products faster with this flexible and efficient approach.

Artificial intelligence has tremendous potential to make production even more efficient, flexible and reliable. As the automotive industry continues toward increased digitalization, data in production environments will be the basis on which entire plants operate.

For example, a major problem that vehicle manufacturers face is unplanned downtime. A digital twin can use AI-based analyses for predictive maintenance. ML-based analytics can collect data and detect anomalies to reduce downtime by scheduling or alerting of maintenance needs before they become problematic.

It is critical to have AI scanning models within the factory that observe and automatically recognize where enhancements or issues may occur. For instance, neural processing units are now part of controllers for object recognition, visual/sensor-supported quality checks in production plants and image-guided robot systems. Industrial edge devices can process data where it is generated, whether that's at the plant or the machine. This makes controllers quicker and more flexible when reacting to unexpected situations. If a ML algorithm spots quality defects, for example, it can respond automatically during runtime.

ML can also be used to train the software that controls the advanced robots on the factory floor. For example, ML can enhance the grasping capabilities or other high-level skills of the robot required for intricate assembly.

All of these factory floor systems can be managed with Mindsphere. A cloud-based Internet of things (IoT) solution, Mindsphere connects products, plants, systems and machines to harness the data generated by IoT and analyze it with advanced AI analytics. It is embedded into a powerful cloud ecosystem (figure 4) enhanced by edge offerings and low-code application development.

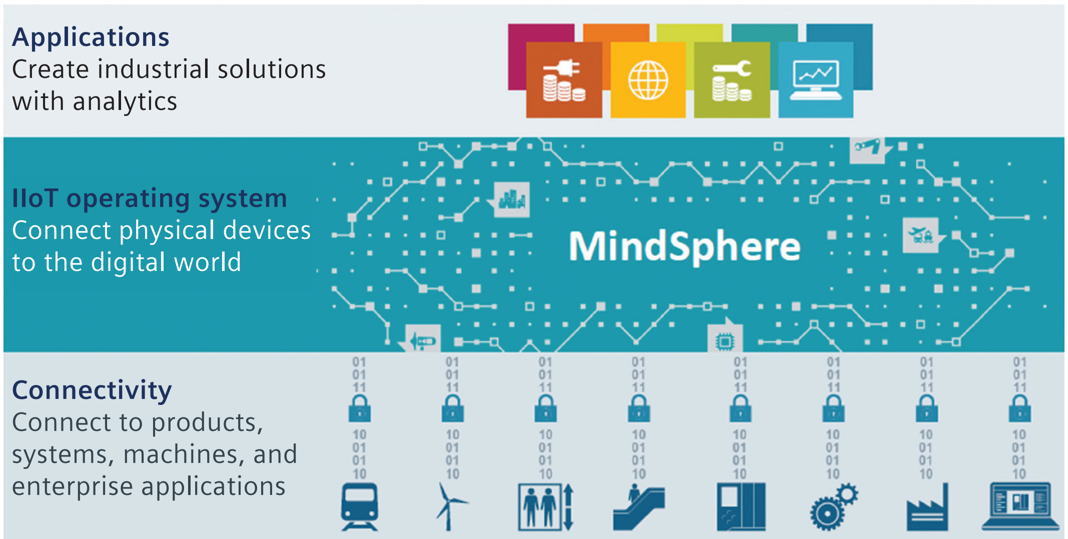

Figure 4: The Mindsphere ecosystem connects devices to analytics.

Connecting with smart city infrastructure

Cities are transforming their infrastructure with digital solutions. For example, by combining real-time sensor and camera data on roads, with an AI system that draws on past history, traffic patterns can be predicted and routes adjusted accordingly. 5G telecommunications technology can be employed for inter-vehicle communication to safely adjust the travel routes of autonomous vehicles.

Siemens is the premier partner for infrastructure digitalization for the Expo 2020 in Dubai. The Expo (figure 5) is a small city that provides an opportunity to develop smart solutions that could be echoed across the world.

One aspect of this project is a Mindsphere application to digitally optimize the Expo, enhance the visitor experience and reduce energy and water consumption. The application will make use of ML and AI to demonstrate the potential of connecting an entire city to the IoT with Mindsphere. It does not take much imagination to see how the connected city would interact with autonomous vehicles. Passenger and freight lanes of traffic could be managed as well as smaller delivery vehicles.

Figure 5: An artist rendering of the Expo 2020 Dubai.

Summary: from chip to city

This paper covers an enticing sample of how some of the tools within the Siemens Xcelerator portfolio of software use AI to optimize designs and create AI-based systems for complex products, such as autonomous vehicles. The potential for growth, efficiency and innovation when using AI is massive, and so is its influence in enhancing the comprehensive digital twin. AI is a critical capability in enabling the future of mobility – from the creation of AI electronics at the heart of the autonomous car to the intelligent design and verification of the whole vehicle as well as the production process within the digital twin before building anything.

AI is also instrumental in connecting to the real world factory and the actual vehicle on the road within the city. All the data can be fed back into the comprehensive digital twin in order to update models, fix issues, optimize systems and predict maintenance issues. The Xcelerator portfolio provides a unique solution from chip to city.

Siemens Digital Industries Software

Headquarters
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
USA
+1 972 987 3000

Americas
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
USA
+1 314 264 8499

Europe
Stephenson House
Sir William Siemens Square
Frimley, Camberley
Surrey, GU16 8QD
+44 (0) 1276 413200

Asia-Pacific
Unit 901-902, 9/F
Tower B, Manulife Financial Centre
223-231 Wai Yip Street, Kwun Tong
Kowloon, Hong Kong
+852 2230 3333

About Siemens Digital Industries Software

Siemens Digital Industries Software is driving transformation to enable a digital enterprise where engineering, manufacturing and electronics design meet tomorrow. Our solutions help companies of all sizes create and leverage digital twins that provide organizations with new insights, opportunities and levels of automation to drive innovation. For more information on Siemens Digital Industries Software products and services, visit siemens.com/software or follow us on LinkedIn, Twitter, Facebook and Instagram. Siemens Digital Industries Software – Where today meets tomorrow.

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