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Mathematics Makes Mobile – Intelligent and Sustainable

The topic of "mobility" has accompanied us at Fraunhofer ITWM since the beginning, which is why we have a large number of exciting projects in this area – across all departments. Even before artificial intelligence became a buzzword, we developed methods to optimize mobility for providers and users, regardless of the mode of transport. Whether rail, car, commercial vehicle or airplane: In the past 25 years, we have included all means of transportation in our research portfolio.

The ITWM-Technikum: Link Between Reality and Simulation

In system and vehicle development, it is key to simulate the physical system properties at an early stage in each of the different phases of the development process. To design, validate and improve new methods, we have special test facilities on site: In the Technikum of the division "Mathematics for Vehicle Engineering", we design and implement our own measurement and testing facilities, hand in hand with our modeling and simulation experts.

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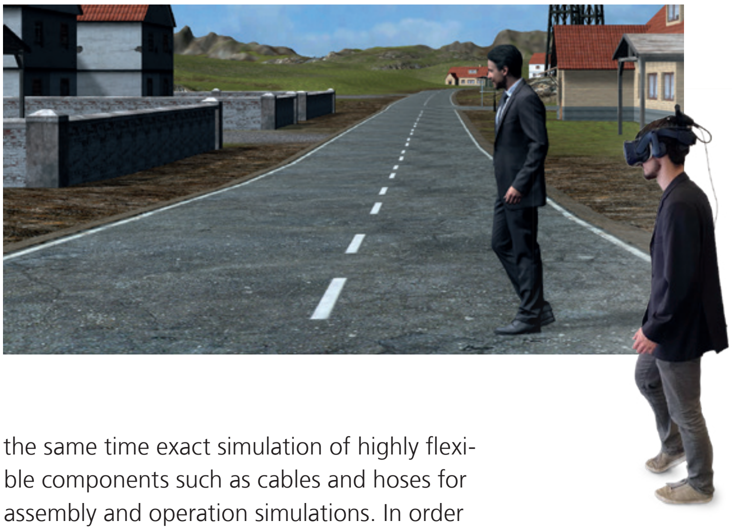
Projectors provide all-round visibility

In the Technikum, we develop, set up and operate our robot-based driving simulator RODOS®, our measuring system for highly flexible components (MeSOMICS®), the 3D laser scanner measuring vehicle REDAR as well as various test benches for cable and hose measurement.

The driving simulator RODOS® (Robot based Driving and Operation Simulator) allows to examine the human machine interaction under perfectly reproducible conditions and without any risk. Designed for a payload of 1,000 kilograms, the motion system (an industrial robot) carries commercial vehicle cabs and car bodies. Inside a ten-meter diameter projection dome, 18 projectors create a seamless projection of an interactive scene. For example, we investigate the interactions between drivers, the vehicle and the environment and validate advanced driving assistance systems together with industry partners. RODOS® is currently the most powerful driving simulator of the Fraunhofer-Gesellschaft.

Take a Walk in VR



Our virtual reality lab enables people to put themselves into complex virtual environments and scenarios, e.g. as pedestrians.

We use the technology both for coupling with driving simulation and for visualizing virtual production sites. In our lab, one or more people experience a virtual reality on a surface of ten by six meters.

Valid Data Thanks to Precise Measurement Technology

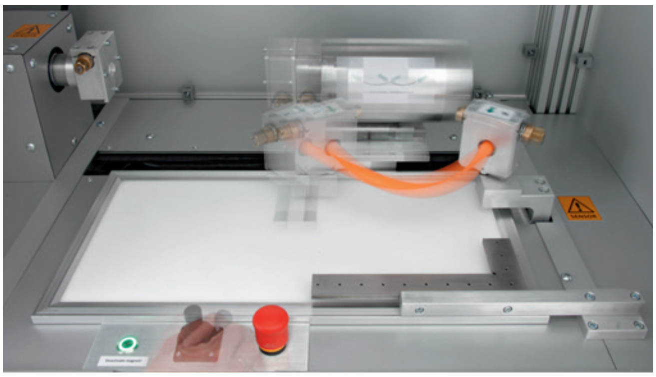
Numerical simulation of real systems or components generally depends on two things:

- On the one hand, a good mathematical model of the system is mandatory to obtain usable simulation results.
- On the other hand, the model must be fed with the correct parameters that also correspond to the real conditions. Often the determination of these parameters is difficult and has to be done individually for each new situation.

The same is true for the IPS Cable Simulation software developed by Fraunhofer FCC and our institute. This enables interactive and at the same time exact simulation of highly flexible components such as cables and hoses for assembly and operation simulations. In order to correctly calculate the deformations and reaction forces of cables and hoses with IPS Cable Simulation, it is necessary to determine the mechanical component properties as model parameters.

For this purpose, the ITWM team has developed, designed, built, and applied for a patent for a highly automated measuring machine (MeSOMICS®) in the Technikum.

MeSOMICS® stands for "Measurement System for the Optically Monitored Identification of Cable Stiffnesses". It is a measurement system for the identification of effective cable stiffness properties.



Bending and curving – the MeSOMICS® measuring machine quickly and easily determines cable properties as they occur later in the vehicle. The measurement runs automatically. Employees simply clamp the cable and start the system.

www.itwm.fraunhofer.de/technikum_en

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Plan – Control – Regulate Traffic Flows

What makes public transport attractive? In view of the rising cost of gasoline and the desired energy transition, creative and sustainable answers to this question are essential. A research group in our division "Mathematics for Vehicle Engineering" is investigating how public transportation pays off for companies and passengers. At the same time, it is also looking at individual transportation: The goal is flow instead of standstill.

The Opel traffic circle in Kaiserslautern is a traffic junction that often impedes the flow of traffic. The Fraunhofer ITWM provides suggestions for the optimization.

Bus and rail passengers want reliable connections, high frequency rates and low fares. Transport companies must operate economically and sustainably: In addition to being attractive to their customers, they also have to consider operating costs and the resulting environmental impact.

LinTim Expands the VMC®-Family

"An optimal traffic system consumes as little energy as possible, covers all needs at the same time and also allows traffic to flow," says project manager Dr. Michael Burger, describing the noble goal. "With our methods and tools from the 'Virtual Measurement Campaign' (VMC®) software family, we can simulate and model individual road traffic highly efficiently, and now we're adding public transport to the mix. That's why we integrated the LinTim software into our VMC® family." The tool was originally developed in the working group of our institute director Prof. Dr. Anita Schöbel.LinTim stands for "Lineplanning and Timetabeling," but it can do much more than lines and timetabling. VMC® LinTim includes algorithms for stop, line, circulation and trip planning, as well as delay management. In addition, it can analyze, assess and optimize the energy demands of deployed vehicles depending on the environment. All methods are integrated into a library and can interact with each other in the various planning stages. VMC® LinTim therefore also finds solutions that are not visible with classical approaches. "In this way, we support traffic planners who, up to now, have mostly used their empirical knowledge as a basis for planning," says Michael Burger.

Simulations Reduce Downtime

In a simulation study, Burger's team is also investigating traffic flows and traffic light control at the Opel traffic circle in Kaiserslautern – a traffic junction in the west of the city that connects the industrial park, highway and bypass. The neuralgic point combines a traffic circle with a traffic light system and regularly produces traffic jams. Our researchers were able to show that an adapted traffic light control – based on traffic data, models and modern mathematical methods – offers great potential for significantly higher flow rates. The tool was developed in the working group of our institute director Prof. Dr. Anita Schöbel.

What New Drive Concepts Do We Need?

Vehicles are on the road for a variety of reasons. Environmental data, models and simulations based on our "Virtual Measurement Campaign" (VMC®) software solution show which drive is suitable for which application.

A parcel delivery service serves roughly the same area every day, braking frequently and starting up again. Perhaps a messenger also leaves the engine running when he brings deliveries to the front door. Employees of craft businesses usually drive to customers' homes where the car is parked for a longer period of time. The target persons are often spread over a larger area than those of the parcel deliverers; thus, cross-country trips are presumably also part of the of the vehicle's usage profile.

The Best Drive for Every Type of Use

Companies involved in vehicle production want to know at an early stage how to develop their vehicles sustainably and in line with demands of the addressed markets. This applies all the more to alternative drive technologies, for which little experience is yet available. Service providers – craft businesses or parcel services – want to put together an optimal vehicle fleet. In view of increased fuel costs and the prospect of innovative drive systems, such planning is all the more important. When is it worth switching to an electric car? Preferably with a fuel cell? And does the installation of a recuperative brake pay off? This technology, which recovers energy during braking, is already in use in rail vehicles and also plays a role in electric vehicles. However, the regenerative brake costs more than a conventional brake.

These few examples alone illustrate the enormous variety of uses on our roads. Michael Burger's team is also investigating which drive is best suited for which application. "To make sustainable drive concepts viable for the future, they must be analyzed and compared under realistic conditions of use. We develop the methods for this and also supply the adequate technology. A major advantage of our offering is that we combine environmental and usage data with analysis and simulation methods to model realistic scenarios for vehicle engineering and development."

Modeling Based on Many Factors

The researchers incorporate a variety of factors into their modeling: route, vehicle, driving behavior and traffic. The basis here is also our software toolbox "Virtual Measurement Campaign" (VMC®). "Our simulation results help public transport operators or freight companies, for example, to put together the optimum drive mix for their vehicle fleet", Michael Burger emphasizes.

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Radome Application Example: Safety Thanks to Terahertz Technology

Modern vehicles contain highly sensitive instruments that must be protected against radiation. One question is particularly important: What material is used for the protective housing?

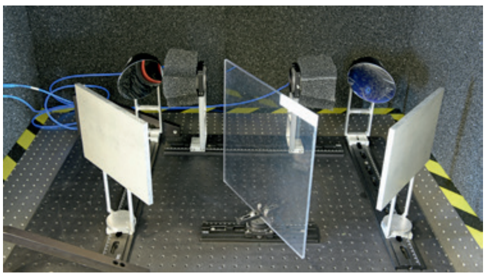
5G works with frequencies up to 40 GHz. The terahertz test uses frequencies from 100 GHz.

Mostly, these are glass fiber composite (GFRP) materials, which are used as multilayer composites. Since GFRPs are permeable to high-frequency radiation, they are used especially where highly sensitive components need to be protected, but the influence of the housing materials on the radiation must remain as low as possible. In the mobility sector in particular, these are mostly classic radar and communication applications, such as distance sensors in automobiles, the 4G and 5G mobile communications standards, and navigation instruments installed in aircraft noses, for example. This is why GRP housings for these applications are also referred to as “radomes”.

Testing Radome Multilayer Composites

The Austrian company 4a manufacturing GmbH produces composite materials for radomes (CIMERA radomes), which are used in the 5G mm-wave and satcom industries, among others. Our “Materials Characterization and Testing” department is investigating for the company their composites for high frequency applications, especially in the range between four and 40 GHz. The structure of the complex multilayer composites is crucial here for the functionality of the materials and the question: at which frequencies do the radomes appear as “electromagnetically transparent” as possible for the desired target application? Up to now, 4a manufacturing GmbH has provided results from material simulations that allow statements to be made about this frequency behavior. These simulations are now additionally backed up by high-frequency measurements.

“Thanks to our shielded measurement chamber, we were able to get into the game here,” says project manager Dr. Maris Bauer. Transmission and reflection measurements on test radomes verify the simulation results. End customers thus have the additional assurance that the materials from 4a manufacturing GmbH are suitable for their application purposes. In addition, our terahertz testing systems allow us to examine the internal structure of finished radomes, for example, in order to detect possible cracks or similar production defects at an early stage.



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www.itwm.fraunhofer.de/terahertz-testing

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Clear the Way for the Modular Inspection Platform

For years, our "Image Processing" department has been working on hot axle box detection on railroad tracks. The aim is to detect hot axle bearings and stationary brakes on passenger and freight trains so that they can be stopped, before serious problems occur.

Sensors in the track bed determine the heat radiation of passing trains without contact and calculate the temperatures from this. If they are outside the standard range, the next control center is automatically informed; typical alarm limits for axle bearings are 100 degrees, for brakes over 300 degrees depending on the type.

Universal Platform for Web Inspection

The requirements in terms of safety and reliability have increased over time: Not only the sensors should work flawlessly, the entire system must work trouble-free and be protected against manipulation from the outside. "For our partner, we are developing an overall system that goes far beyond pure temperature measurement," says project manager Thomas Redenbach, describing the collaboration with Progress Rail Inspection and Information Systems in Mannheim. "We are implementing the system as a modular platform: the individual components communicate in encrypted form via secure communication protocols. Users authenticate themselves in a multi-stage login process to protect the platform as well as possible against hacker attacks." In addition, subsystems can be redundant, which provides increased fail-safety.

The sensor technology is flexible: as required, modules can be retrofitted to detect protruding loads on freight trains, flat spots on wheels or dragging components on the track.

Fault detection during drive-by: Acoustic sensor detects wear condition of axle bearings.

New are acoustic sensors that can detect incipient bearing damage from the noise of a passing train.

Sensor Fusion Enables Predictive Maintenance

The universal platform can combine measured values from different sensors: For example, temperature and acoustic data can be used to determine the wear condition of axle bearings. It is also possible to network several locations in order to track trains over time. This data can be used to detect impending component failures at an early stage and to adapt maintenance cycles to actual wear. The system will go into test operation this year.

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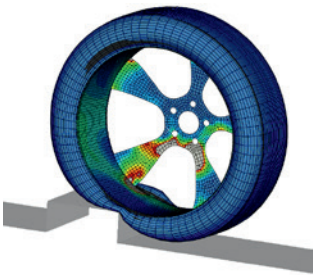
Diverse Mobility Projects at The Fraunhofer ITWM

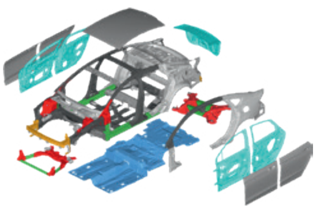
Electromobility, water management, filter materials – we at Fraunhofer ITWM are researching many facets of "mobility". At this point, we have compiled some projects into which we give short insights.



"CDTire": Realistic Simulation of Tires

CDTire is a tire model family for passenger car, truck and agricultural tires, that supports engineers from vehicle and tire manufacturers in almost all simulation scenarios in modern vehicle development processes. Special focus on tire dynamics and interaction with 3D-road surfaces accurately captures the vibrations in both amplitude and frequency behavior with additional capabilities in static and stationary tire behavior. Access to constructional as well as material also allows for quick what-if studies.

www.itwm.fraunhofer.de/cdtire_en



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ALMA: Lightweight Construction and Ecological Design for Electric Vehicles

E-mobility and lightweight construction are two building blocks of modern vehicle development to drive the energy transition. The ALMA project is focusing on them. Nine European organizations are working to develop more energy-efficient and sustainable vehicles. Companies from research and industry are optimizing the range of electric vehicles by, among other things, reducing the weight of the overall vehicle. Our team supports with mathematical simulation expertise. See more in the video online.

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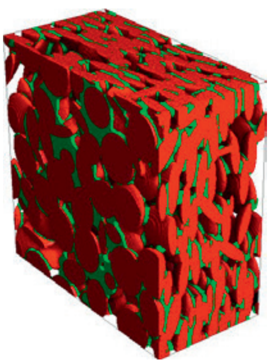

Battery cells for e-mobility

Develop battery cells virtually? The simulation software BEST (Battery and Electrochemistry Simulation Tool) developed at our institute is currently used by experts in the automotive industry for the development of lithium-ion battery cells. In the ABBA-VEEB project, a much more broadly applicable design platform is being created based on BEST – both for the virtual design and for the virtual testing of current high-performance batteries for the e-mobility of tomorrow.

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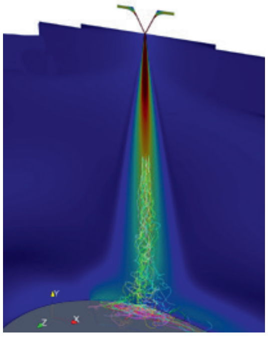
Check Filter Nonwovens Virtually

Filters, such as those installed in cars, have to meet increasingly stringent requirements. At the same time, the products should be ready for the market more quickly. Simulations support the developers in this balancing act. In the research project "ProQuIV", an interdepartmental team of the Fraunhofer ITWM has optimized the entire production chain of nonwovens. The findings also benefit the automotive industry in the further development of cabin and pollen filters.



www.itwm.fraunhofer.de/ proquiv-en

MESHFREE: Application Example Water Management

With MESHFREE, we have been providing an innovative software product for grid-free simulation of physical processes in cooperation with Fraunhofer SCAI since 2018, combining the expertise of both institutes in the field of grid-free scientific computing. MESHFREE is based on a general material model that is also suitable for use in water simulations: driving through puddles, rain on the windshield - the automotive company PORSCHE uses MESHFREE for its water management. Find out more on our websites and in the corresponding video!

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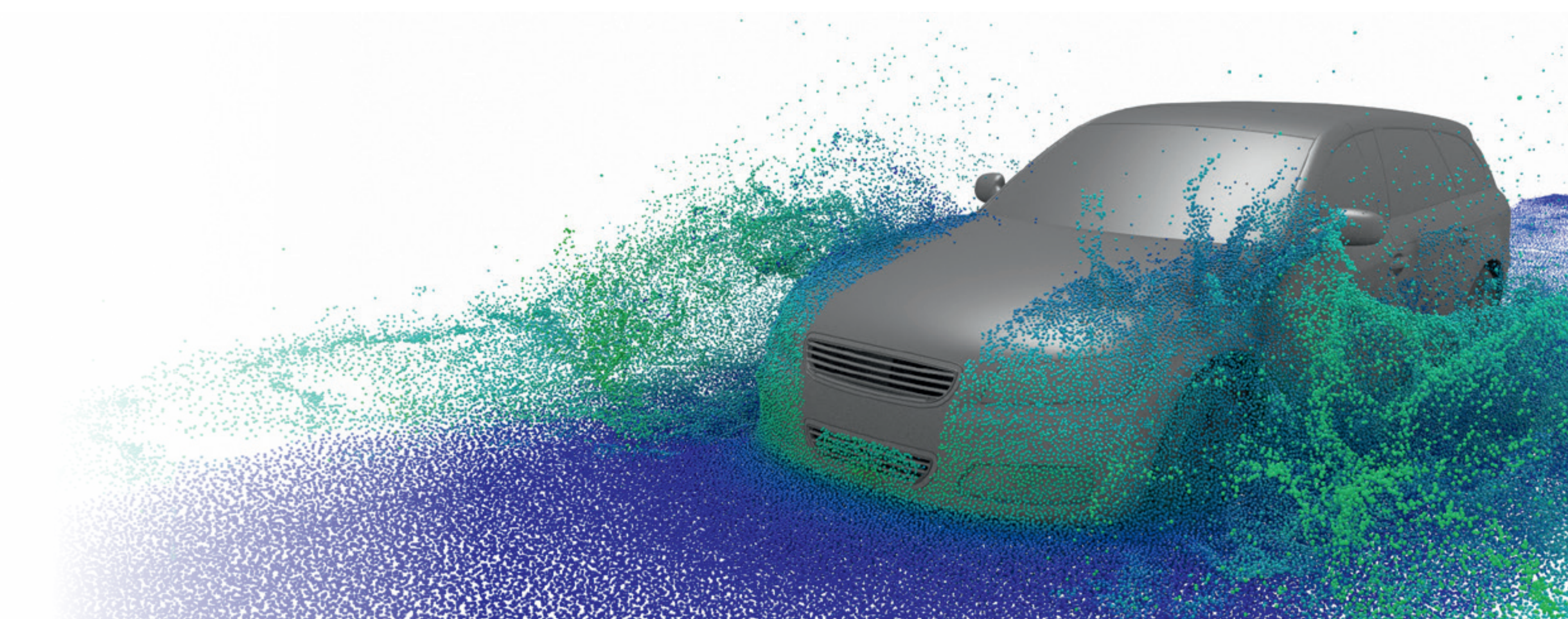

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European Data Cloud for the Mobility of the Future

The "GAIA-X 4KI" project, part of the European "GAIA-X" project, offers a glimpse into the future. A consortium of industry and research with 16 partners is developing concrete services for the automotive industry in the European computing cloud with the help of artificial intelligence (AI). The aim is to make connected and automated driving safer.

Huge amounts of data are generated when planning, building and operating vehicles. The team in GAIA-X 4 AI uses AI methods to utilize this data efficiently and securely. To do this, our researchers from "High Performance Computing" bring together data and infrastructure, hardware and software. To achieve this, they use "containers" in which they pack the applications and move them between the respective environments like in a marshalling yard. The challenge: to get the containers on the track in such a way that the available computing resources are used optimally. This results in complex mathematical optimization tasks that can only be solved efficiently by considering the entire system of hardware, software and application algorithms. In addition, the users should be able to use their containers not only on their own premises, but also on a platform that is accessible to everyone, without any major effort.

Test Track for Mobility of Tomorrow

In the GAIA-X 4 KI project, the Offenburg University of Applied Sciences, the German Aerospace Center (DLR), and the ITWM team are each building a demonstrator. According to project leader Dr. Dominik Straßel, their special feature is: "Normally, data is uploaded to a cloud and processed there; but downloading the result is expensive. That's why we're taking a different approach: We calculate directly where the data is, i.e. at the project partners' locations. This not only saves money, but also energy." The researchers are focusing on use cases from the automotive industry, aiming to bring automated and connected driving into practice. The German Federal Ministry of Economics and Climate Protection (BMWK) is supporting the project financially.

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"I wish us to be reliable and environmentally friendly on the road!"

Prof. Dr. Anita Schöbel
AI Pilot for Mobility

Three Questions For..

Intelligent systems and networked processes: With the help of AI and machine learning, we are shaping the traffic and vehicle development of tomorrow – sustainably, efficiently and safely. As the AI Pilot for Mobility of the state of Rhineland-Palatinate, our institute director Prof. Dr. Anita Schöbel, together with her advisor Dr. Henrike Stephani, disseminates the knowledge needed for the application of artificial intelligence in the mobility industry.

AI pilot Prof. Dr. Anita Schöbel in her lecture on the topic "Sustainable computing today and in the future" at the Science Notes in April 2022

1 What is particularly important to you about mobility?
The connection of the individual sectors, i.e. that the various modes of transport such as car, bus and train, walking, bicycle or even scooter are considered together and jointly designed to meet demand

2 What are your main areas of research?
In research, I myself am primarily concerned with the optimization of public transport. Typical questions here are: Which lines should be set up? How do you get a good timetable? What structure should the fare system have? How do you react in the event of delays?

3 What do you wish for mobility in the future?
I wish for us to be efficient, reliable and environmentally friendly on the road in the future!

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