Looking Far Ahead and Around Corners with **Digital Twins**

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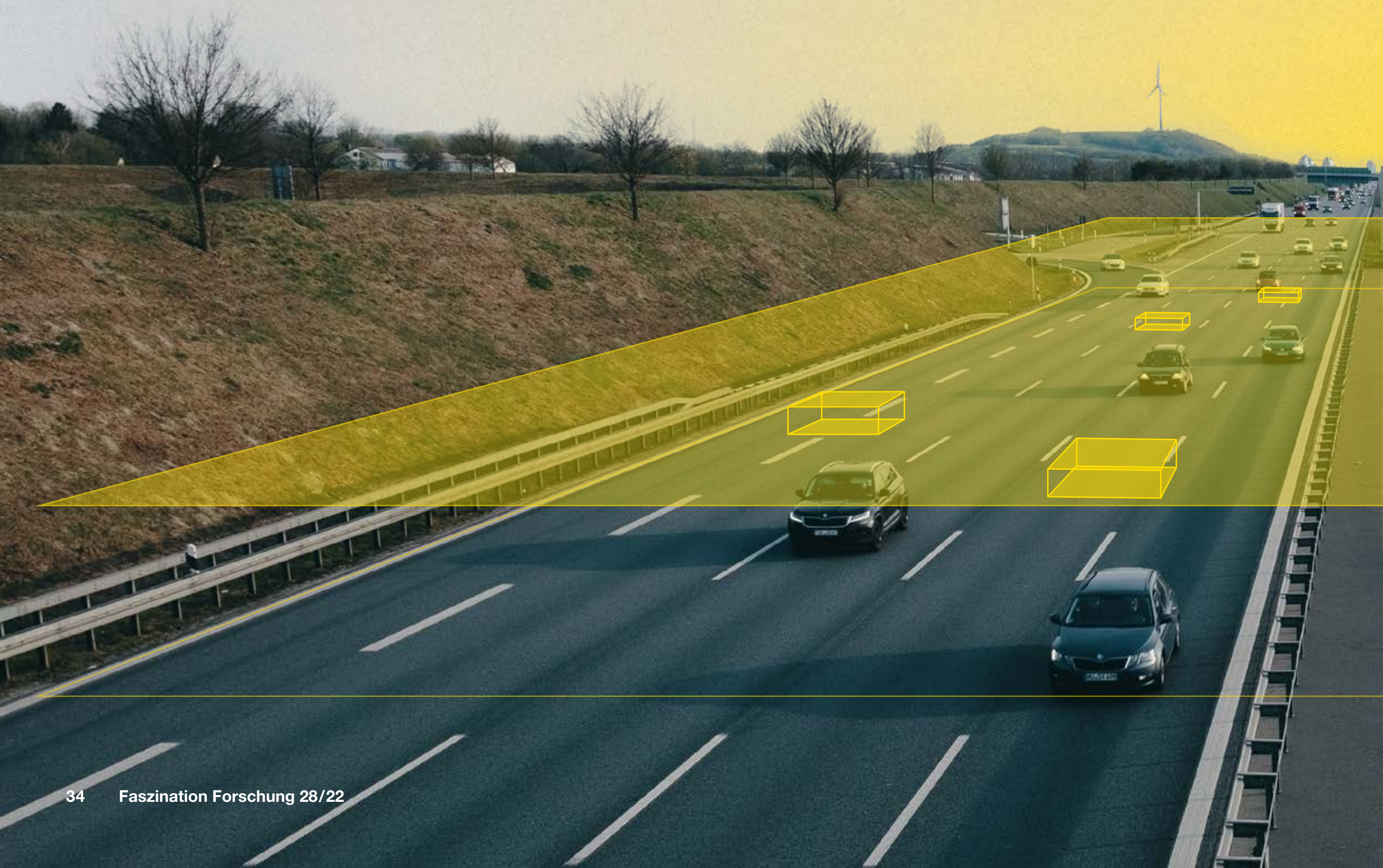
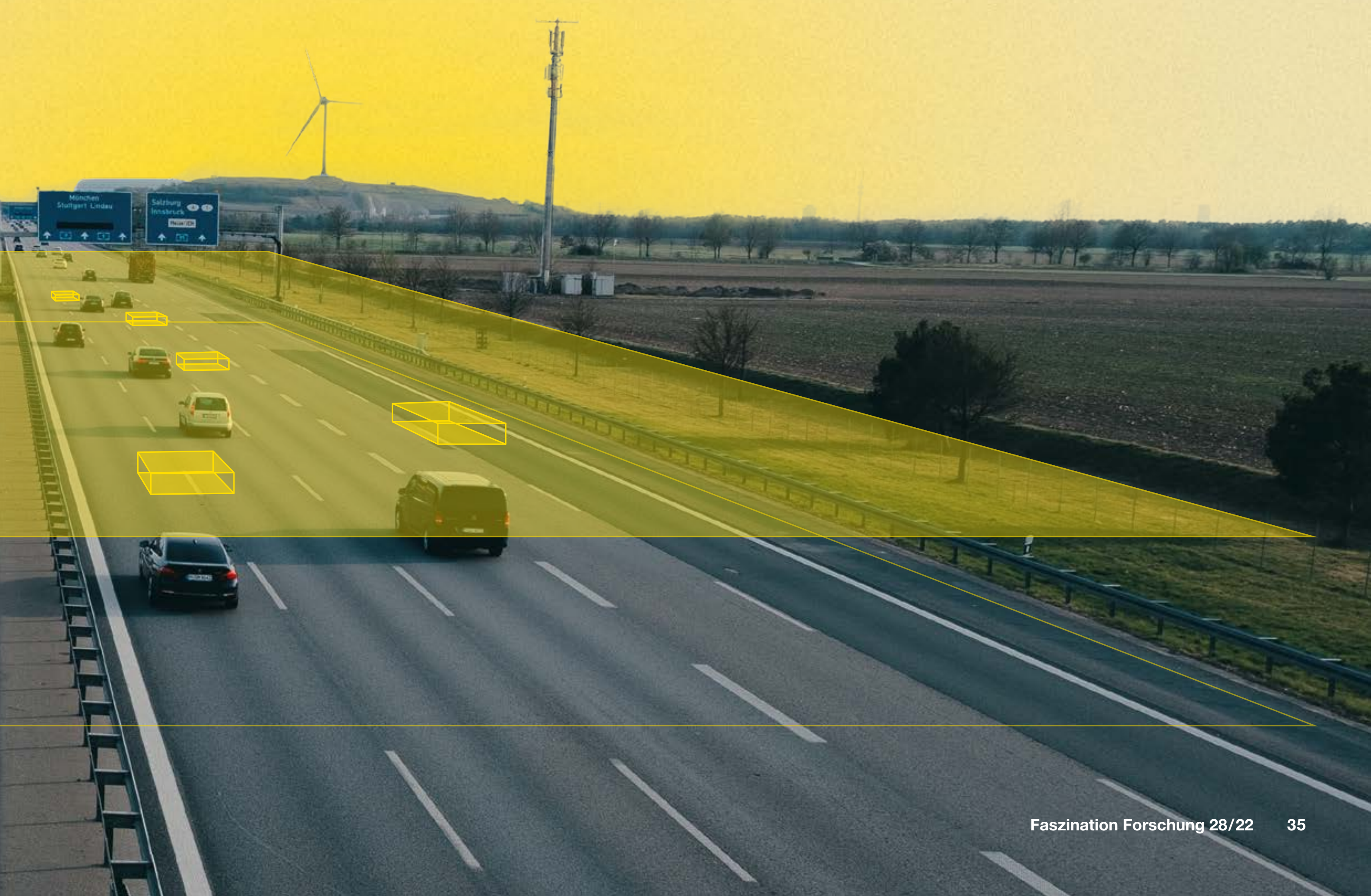
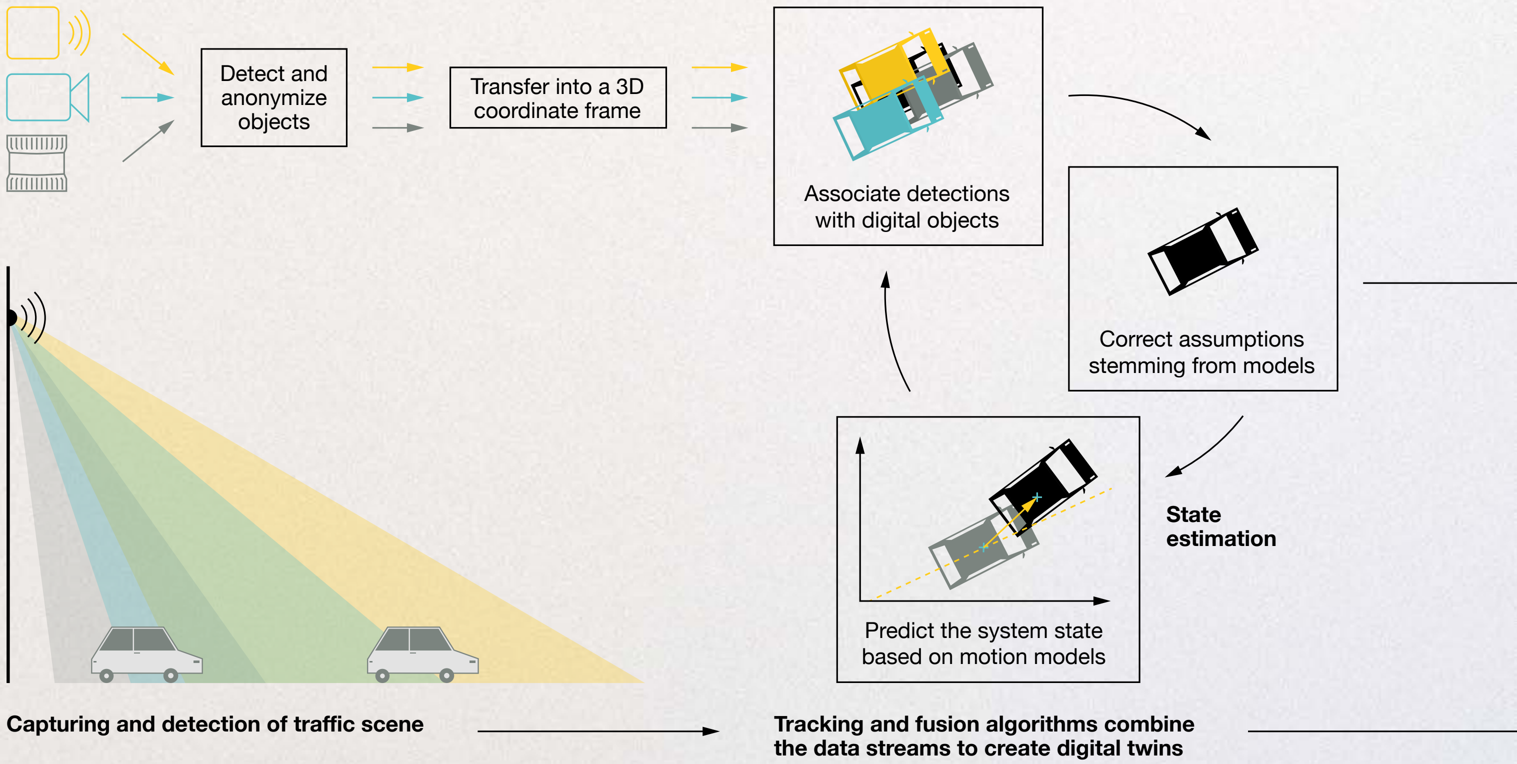


Picture credit: ediundsepp;
Graphics: ediundsepp (source: TUM)

How can we control and regulate traffic to improve safety and convenience while also making the best possible use of existing infrastructure? In the Providentia++ project, Professor Alois Knoll and his team have developed a digital twin using data from roadside sensors to depict the current traffic situation in a machine-readable form in real time.





Gesamter Artikel (PDF, DE): www.tum.de/faszination-forschung-28

Um die Ecke schauen mit dem digitalen Zwilling

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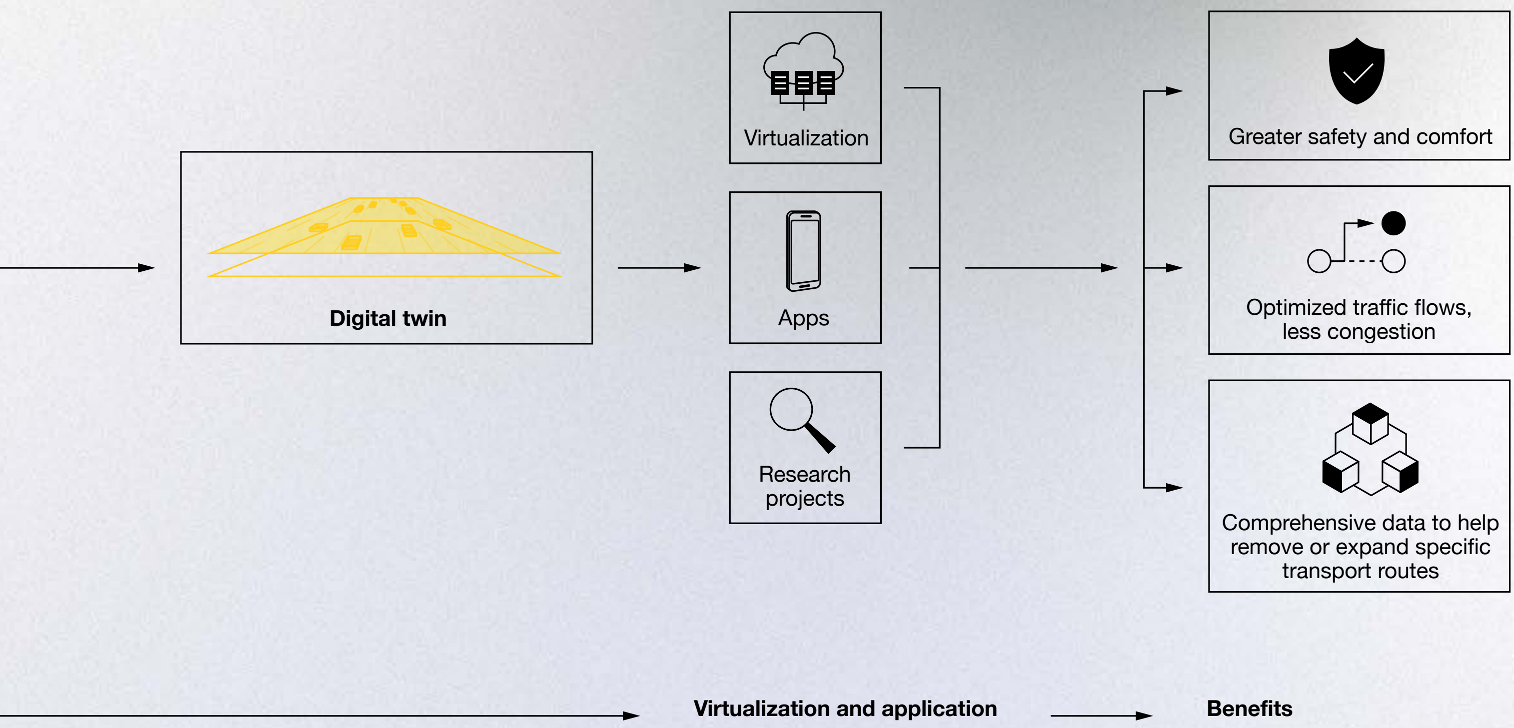
Im Projekt Providentia++ (Proaktive Videobasierte Nutzung von Telekommunikationstechnologien in innovativen Autoverkehr-Szenarien), das vom Bundesministerium für Digitales und Verkehr gefördert wird, entwickeln Prof. Alois Knoll und sein Team am Lehrstuhl für Robotik, Künstliche Intelligenz und Echtzeitsysteme der TUM ein System zur Verkehrsüberwachung in Echtzeit. „Mithilfe unterschiedlicher Sensoren beobachten wir alle Verkehrsteilnehmerinnen und Verkehrsteilnehmer und übertragen deren Position und Geschwindigkeit in einen digitalen Zwilling, welcher das Geschehen virtuell abbildet. So sind wir in der Lage, nicht nur aktuelle Staus und Gefahrensituationen rechtzeitig zu erkennen, sondern sogar in die Zukunft hochzurechnen, wann eine Gefährdung oder ein Stau entstehen könnte“, so Knoll. An dem Projekt nehmen zahlreiche Firmen teil, Knoll hat die Konsortialleitung übernommen. □

While at first glance appearing deceptively unspectacular, this project could well bring about one of the most significant steps forward in the history of road traffic. All there is to catch the eye are a few cameras and small boxes attached to overhead gantry signs over a five-lane carriageway in Garching-Hochbrück, just north of Munich, along with a few radio masts. And yet, this project has its sights set on nothing less than a revolution, as researchers strive to pave the way for the digitalization of road traffic. Just as Google Maps has digitalized road maps, Wikipedia has taken the sum of the world’s knowledge online, and Zoom has made conferences digital, Providentia++ can depict current road traffic – that is, the position and speed of all road users, including cyclists and pedestrians – in a digital form, making this data available to all. This real-time view offers wide-ranging advantages, from prompt hazard warnings and the ability to avoid traffic jams, to distributing traffic flows with optimal efficiency.



Graphics: ediundsepp (source: TUM)

A win-win-win situation

Research projects rarely feature such a close connection between theory and practical application as Providentia. In early 2020, Prof. Alois Knoll and his team at the Chair of Robotics, Artificial Intelligence and Real-time Systems at TUM took over consortium leadership for the follow-up project Providentia++ from fortiss, a research institute of the Free State of Bavaria. “The technology we develop delivers benefits in several respects,” he says. “It provides greater safety and convenience for road users; it helps cities, municipalities and motorway operators to optimize traffic flows, and it gives urban planners data they can use to improve transport infrastructure.” At the same time, Providentia++ (an abbreviation of its German name, which translates to Proactive Video-based Use of Telecommunications Technologies in Innovative Traffic Scenarios) operates at the cutting-edge of research, fusing together data streams from various different sensors, using artificial intelligence to support analysis, networking transmission points and, for the first time, making real-time data on the transport scene available to download. Numerous companies are involved in the €17 million project, which (like its predecessor project Providentia) is supported by the Federal Ministry for Digital and Transport with around €11 million of funding.

The eponymous goddess, who adorned the reverse side of coins in Ancient Rome, was the personification of divine foresight and the emperor’s care for his citizens. “Likewise, Providentia++ preempts problems by giving us a complete and comprehensive picture of current traffic in real time using a digital twin,” the professor explains. “Various sensors enable us to observe all road users and transfer their position and speed into a digital table, which – similar to a computer game – virtually depicts what is going on. As a result, we are in a position not only to promptly identify current traffic jams and hazardous situations, but also to predict when a hazard or traffic jam might arise in future.” Corresponding notifications can then be sent to drivers via mobile telephones, for example, when they have downloaded the Providentia app. Another option would be to display messages on sat-nav systems. ▷

Sensors on road bridges

In the predecessor project, Providentia, which ran from 2017 to 2020, the researchers initially fitted cameras and radars to two sign gantries on the A9 autobahn north of Munich. In the follow-up project, Providentia++, they have expanded to what is now a 3.5 kilometer long test section, continuing along the B471 federal highway as it branches off from the A9 and leads into a built-up area. The institute's driving simulator in Hochbrück allows users to experience the digital twin live. "We can cruise along with the traffic on the A9," says doctoral student Walter Zimmer. "But we can also monitor the current situation at the junction in Hochbrück." Even a domestic PC is enough to observe traffic flows live, as they happen. In addition, the Chair's team makes the A9 datasets available for commercial and scientific purposes, free of charge.

At present, the team has 75 sensors in use, from cameras to radar and lidar systems, constantly capturing data about the current traffic situation. "We very intentionally combine different sensors," says Alois Knoll. "It's sort of like the human senses: sight and sound complement each other to form an overall picture. That being said, combining all of the different data is a considerable technical challenge."

Unsurprisingly, the processing involves large volumes of data: a single area-scan camera, for example, generates around 400 megabits of data per second, or about 4 terabytes every day. "First, high-performance computers deployed on-site reduce this volume of data down to the essentials," explains doctoral student Christian Creß, outlining the process. "This means that, ultimately, we only receive a few bytes for each traffic object. It's only by cutting the data down in this way that we can actually transfer data in real time." This is achieved using directional radio relays. Creß also mentions the challenges that they had to overcome in the initial phase of the project. "Gantry vibrations and poor weather conditions impair data quality significantly," he says. "We had to adapt to that."

The researchers dispel any concerns that Providentia++ could lead to blanket monitoring of road users by highlighting that no personal data is ever collected. Each object is anonymized in the first step of the process, with license plates and faces made unrecognizable. In subsequent steps, the data processing focuses solely on the anonymized positional data. The researchers have also put measures in place to make the transmission highly secure.

▷

3.5

kilometer long test section

75

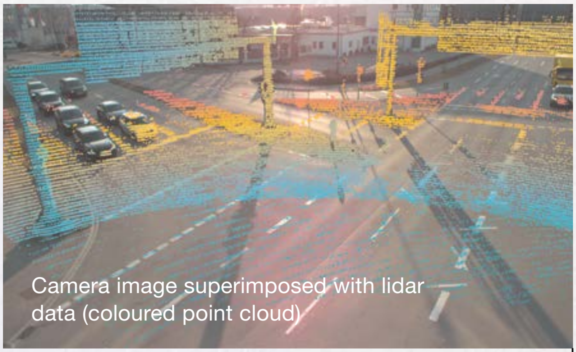
sensors in use

20

gigabits per second of raw data

Sensors at the signal systems record traffic events. A digital twin is constructed in real time. On this basis, traffic light phases can be controlled automatically and adaptively, for example, or road users can be warned of dangers.

Picture credit: Walter Zimmer (TUM, 2022);
Graphics: turbosquid, ediundsepp (source: TUM)



Camera image superimposed with lidar data (coloured point cloud)

Sensors and their advantages

Area-scan camera: Records all vehicles and pedestrians in a visible area

Radar: Detects road users by using reflected radio waves, recording their distance and speed; also works well in the dark and in foggy or rainy conditions, good depth resolution

Lidar: Detects road users by using reflected laser beams, recording their distance; works well in darkness, high precision

360° camera: Provides an overview

Event-based camera: Only reacts when something changes in the field of vision. Saves energy and reduces the volume of data generated as it only saves moving images

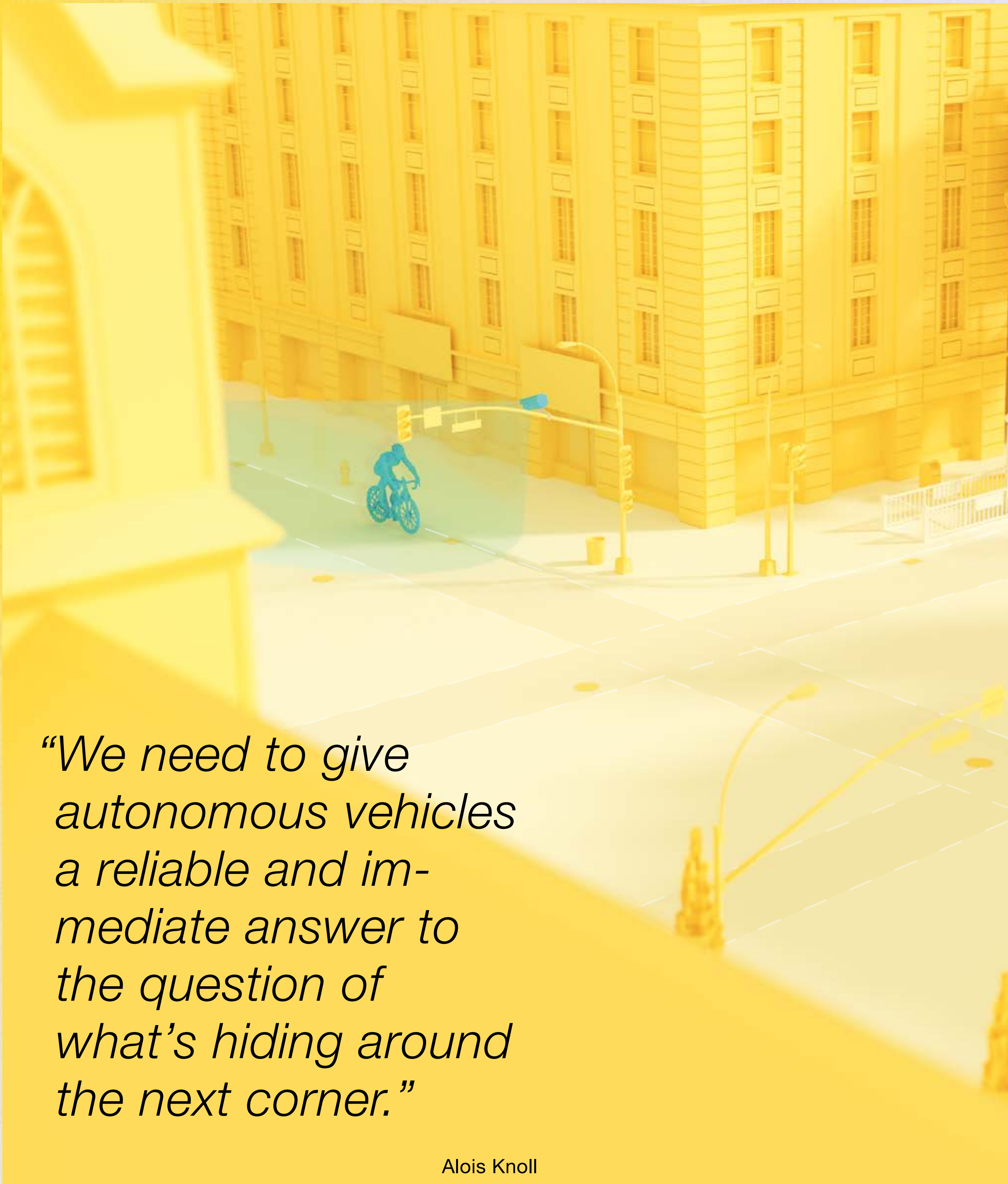
Top: Cameras, lidar and radar sensors mounted on road bridges register the traffic scene. Middle: Project lead Venkat Lakshmi (left) and Walter Zimmer check a lidar at the intersection. Bottom: The team (from left): Leah Strand, Andreas Schmitz, Venkat Lakshmi, Walter Zimmer and Christian Creß.

Picture credit: Stefan Woidig

Prof. Alois Christian Knoll

After positions in Stuttgart, Berlin and Bielefeld, Alois Knoll arrived at TUM in 2001 and now leads the Chair of Robotics, Artificial Intelligence and Real-time Systems. Alongside many other activities, he served as Program Principal Investigator at TUMCREATE in Singapore from 2011 to 2021. This time gave him a sense of optimism that modern technology can deliver positive change in the transport system, hoping that even a city like Munich can follow the example of a supercity like Singapore. As part of his work to promote this, he sets great store by close cooperation with business and is deeply committed to young people's training and education.

Looking around corners with digital twins: Cars will know in real time what's happening at the intersection.



"We need to give autonomous vehicles a reliable and immediate answer to the question of what's hiding around the next corner."

Alois Knoll

Graphics: turbosquid, ediundsepp (source: TUM)

"Our high-security data encryption and the safeguards in place to protect system access points means that external users cannot gain access," emphasizes Knoll.

Fewer severe injuries when turning right

Even though the technical infrastructure of the prototype exists and the digital twin functions effectively, the project is still a few steps away from everyday practice, which requires installing the system across entire cities. Above all, there is still the need to develop easy-to-install, low-cost and modular sensor systems, which will primarily require support from the industry.

Despite this, the overall concept is not some pie-in-the-sky futuristic dream. The newly developed technology in its current modular form can be installed immediately and its full impact realized today. For example, Munich's police department has reported that more than 90 cyclists were severely injured in 2020 alone because "car and truck drivers failed to see the cyclist when turning right" – and this figure is rising. Alois Knoll considers this irresponsible. "Providentia++ could prevent such accidents by providing a warning in the car before it turns right," he emphasizes. "An intelligent solution would certainly be better than the small side mirrors we have today. The costs would be manageable for the city, too."

The future use of the technology developed in the Providentia++ project will not only be wide-ranging but will also lead to it becoming indispensable, as it can support all levels of driver assistance through to autonomous driving. In levels 1 and 2, which describe assisted driving, the system communicates via an interface to provide information in real time that assistance systems can process. In levels 3 to 5, which describe automated driving systems, a constant overview of the current situation is essential, as autonomous vehicles do not have the benefit of a driver's intuition. Better sensor technology therefore needs to compensate for this. "In effect, we constantly need to give the vehicle a reliable and immediate answer to the question of what's hiding around the next corner," says Knoll. He and his staff at the Chair benefit from their extensive expertise in working with robotics. "Classic robotics is, to an extent, the nursery school for autonomous driving."

■ *Brigitte Röthlein*