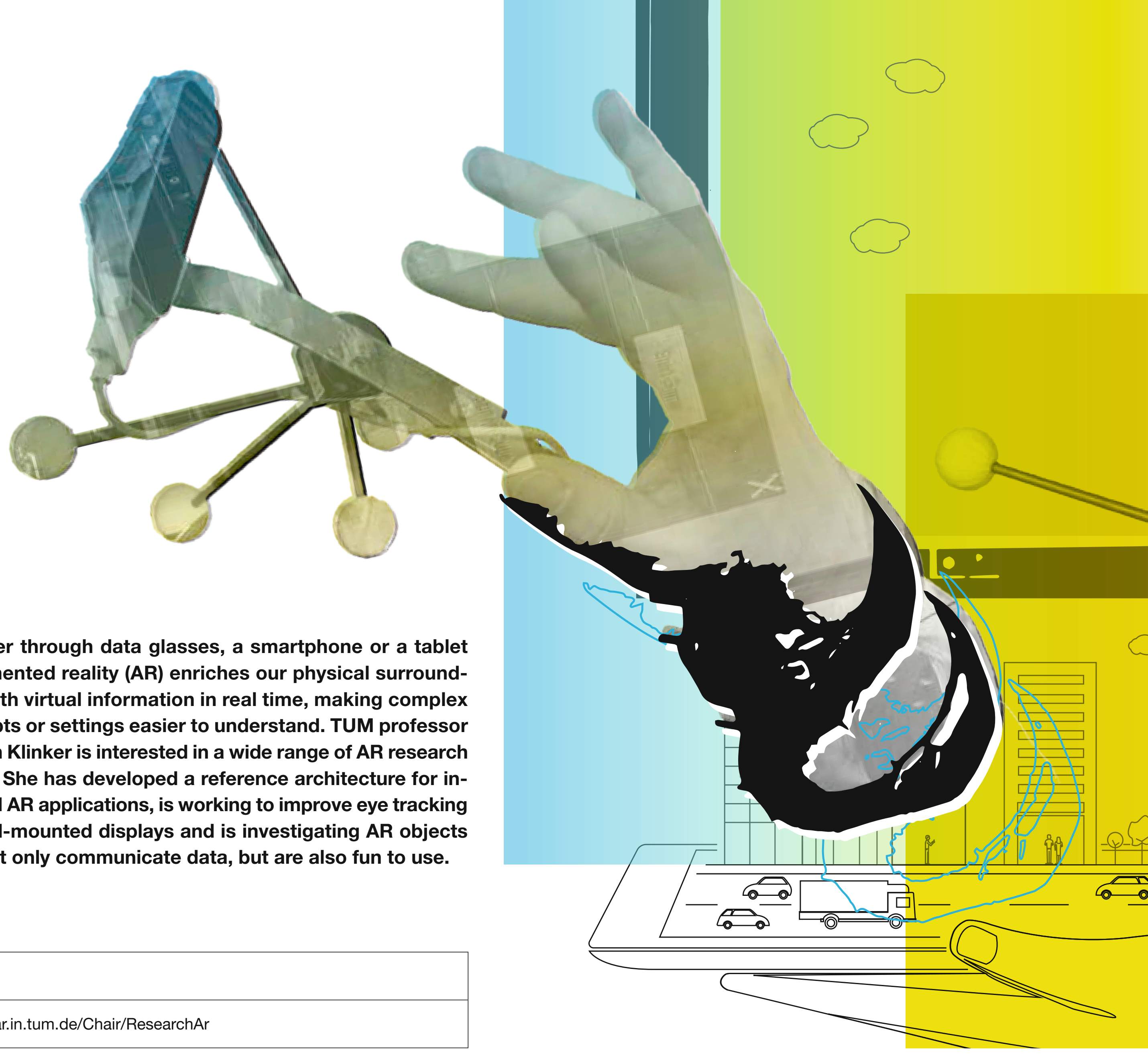
Looking Ahead – **Into our Real and Virtual Future**



Whether through data glasses, a smartphone or a tablet – augmented reality (AR) enriches our physical surroundings with virtual information in real time, making complex concepts or settings easier to understand. TUM professor Gudrun Klinker is interested in a wide range of AR research topics: She has developed a reference architecture for industrial AR applications, is working to improve eye tracking in head-mounted displays and is investigating AR objects that not only communicate data, but are also fun to use.

Link
campar.in.tum.de/Chair/ResearchAr

Graphics: ediundsepp; Picture credit: Eckert

Augmented reality put to use in the humanities

Klinker’s team developed a game in which players build a Celtic village. Markers on the playing cards correspond to houses with various functions. Using an AR app, players can visualize them in 3D and find additional resources inside, including information about Celtic life or rune stones.

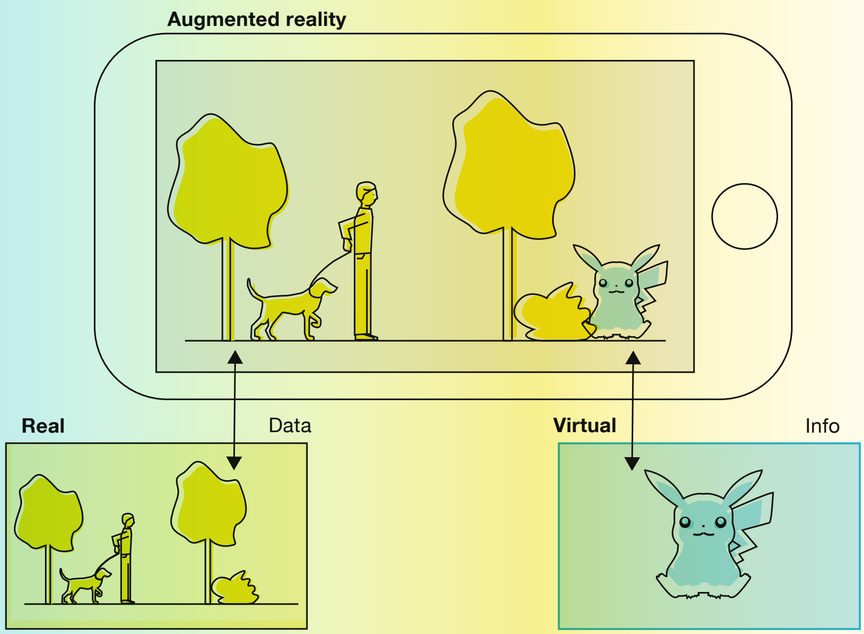
Gitta Rohling

Weiter Blick – in die reale und virtuelle Zukunft

Dank eines Trackingsystems und Markern zeigt das Display einer Bolzenschweißpistole dem Monteur, wo sich die Schweißpunkte befinden und wie die Pistole geneigt werden muss, so dass sich der Bolzen gezielt platzieren lässt. Entwickelt hat das Gerät Prof. Gudrun Klinker in einem Forschungsprojekt mit der BMW AG. Das Beispiel zeigt: AR reichert die reale Welt in Echtzeit mit virtuellen Daten an – und erweitert sie damit. Das kann per Smartphone, Tablet oder Datenbrille passieren. Auf jeden Fall: „AR ist das ideale Hilfsmittel, um mir Informationen aus meiner Umgebung sinnvoll an die Hand zu geben und gezielt nutzbar zu machen“, erklärt Klinker.

In der Produktionsplanung lässt sich AR ebenso einsetzen wie in der Wartung und Reparatur. Allerdings: Für AR-Anwendungen existieren in der Regel geschlossene Systemwelten. Eine Referenzarchitektur, die die Gemeinsamkeiten zwischen unterschiedlichen Anwendungen beschreibt, hat Gudrun Klinker im Forschungsprojekt „ARVIDA“ entwickelt. Die Partner aus Industrie und Forschung haben verschiedene Anwendungen in der industriellen Produktentwicklung und Produktionsplanung auf ihre Gemeinsamkeiten hin analysiert und schafften aus Einzelfällen Standards. Ein Beispiel ist ein standardisiertes Tracking, mit dem Bewegungsabläufe von Fahrern ebenso wie Fahrzeugbauteile getrackt und in eine virtuelle Umgebung eingespielt werden können. Nach drei Jahren Forschung ist im Jahr 2016 eine offene, auf etablierten Web-Technologien basierende Referenzarchitektur entstanden. Produktentwickler und Produktionsplaner haben damit einen Werkzeugkasten an der Hand, mit dem sie schneller, flexibler und kostengünstiger als bisher neue AR-Anwendungen zusammenstellen können.

Bei weiteren Forschungen beschäftigt sich Klinker mit der Frage: Wie viele virtuelle Informationen kann der Mensch aufnehmen, ohne die Konzentration auf das reale Geschehen, zum Beispiel beim Autofahren, zu verlieren? Diese Frage zieht gleich eine weitere nach sich: Wie kann der Mensch animiert werden, etwas zu tun? Klinker entwickelt derzeit beispielsweise gemeinsam mit Ernährungswissenschaftlern und Medizinern ein Trinkglas für ältere Menschen. Das Glas stellt fest, wie viel der Mensch getrunken hat und erinnert ihn bei Bedarf spielerisch ans Trinken – indem es etwa aufhört, auf einem integrierten Display die Fotos der Enkel zu zeigen. „Die Technik ist sehr weit gediehen, jetzt können wir uns auch auf die Psychologie konzentrieren“, freut sich Gudrun Klinker. □



How AR works

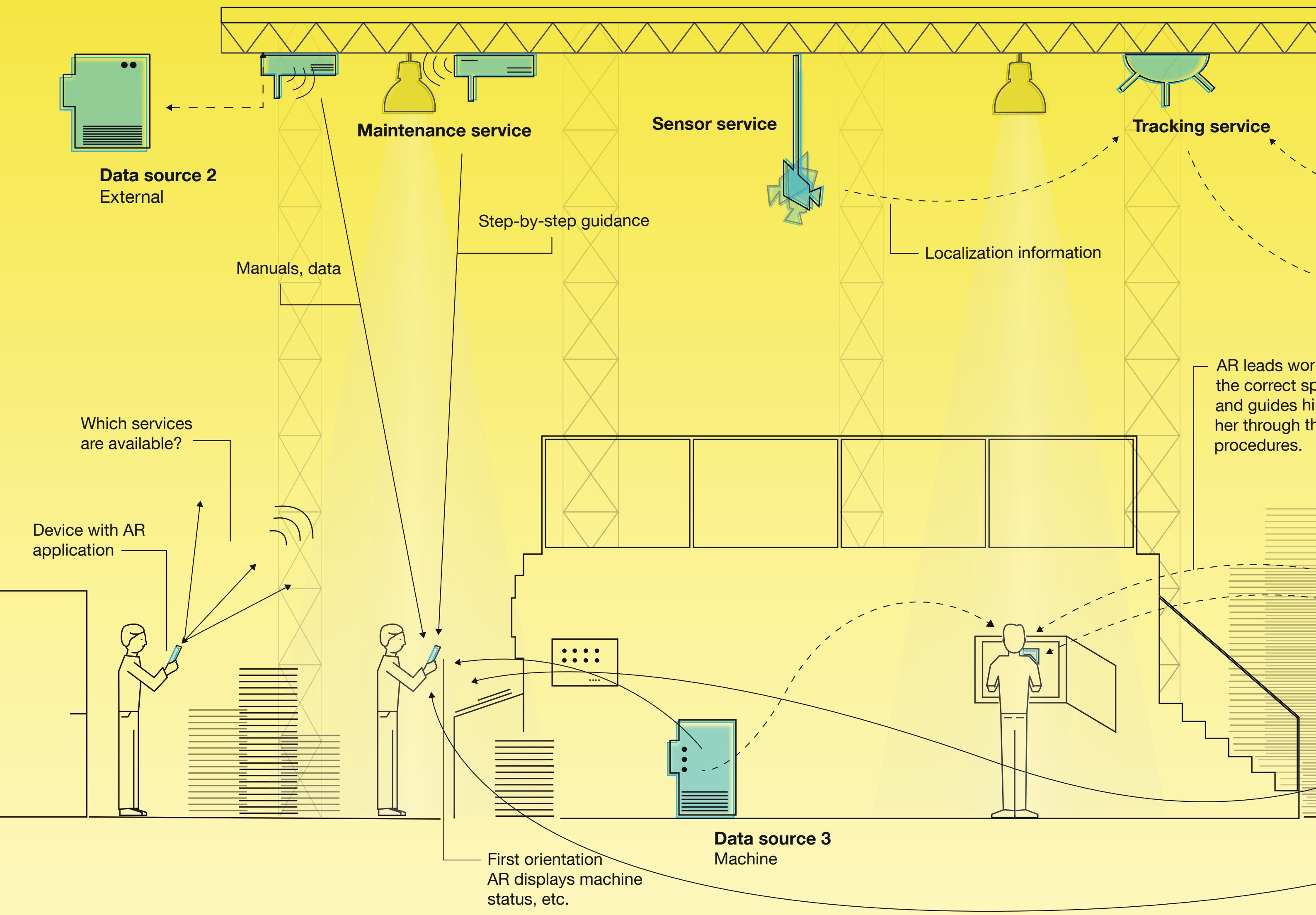
Augmented reality adds extra, virtual information to the real world in real time.

> *"AR is the ideal way to place valuable information about my surroundings at my fingertips and enable me to use it in a really productive way."*
>
> *Gudrun Klinker*

With a single, well-aimed shot, the bolt enters the vehicle body. And – pow! – the second accurate hit follows just seconds later. This speedy, sure-fire success comes courtesy of an augmented reality stud welding gun. TUM professor Gudrun Klinker developed this device in a research project with BMW AG, and from 2003 the company used it for years in prototype manufacturing. Using a tracking system and markers, the gun's display shows the technician where the weld points are located and how to place the device to position each bolt with high precision.

As this example shows, AR creates an interactive, real-time connection between physical objects (like the car frame) and virtual information (the welding points), which appear in the same environment. Tracking systems and markers align both worlds geometrically and synchronously so that the virtual objects are positioned exactly. In short, AR adds extra information to the real world in real time – and thus expands it. This might take place via a smartphone, tablet or head-mounted displays: "AR is not limited to any specific device or particular purpose. You only need to think of your car: a talking navigation system, a vibrating steering wheel – all that is AR too, since it gives us additional information," underscores Klinker. The stud welding gun was originally designed for a head-mounted display, for instance. But since the tip of the gun had to be positioned with high accuracy, a built-in display on the device proved the better choice. But regardless of the device, according to Klinker: "AR is the ideal way to place valuable information about my surroundings at my fingertips and enable me to use it in a really productive way." ▷

Graphics: ediundsepp; Picture credit: Eckert



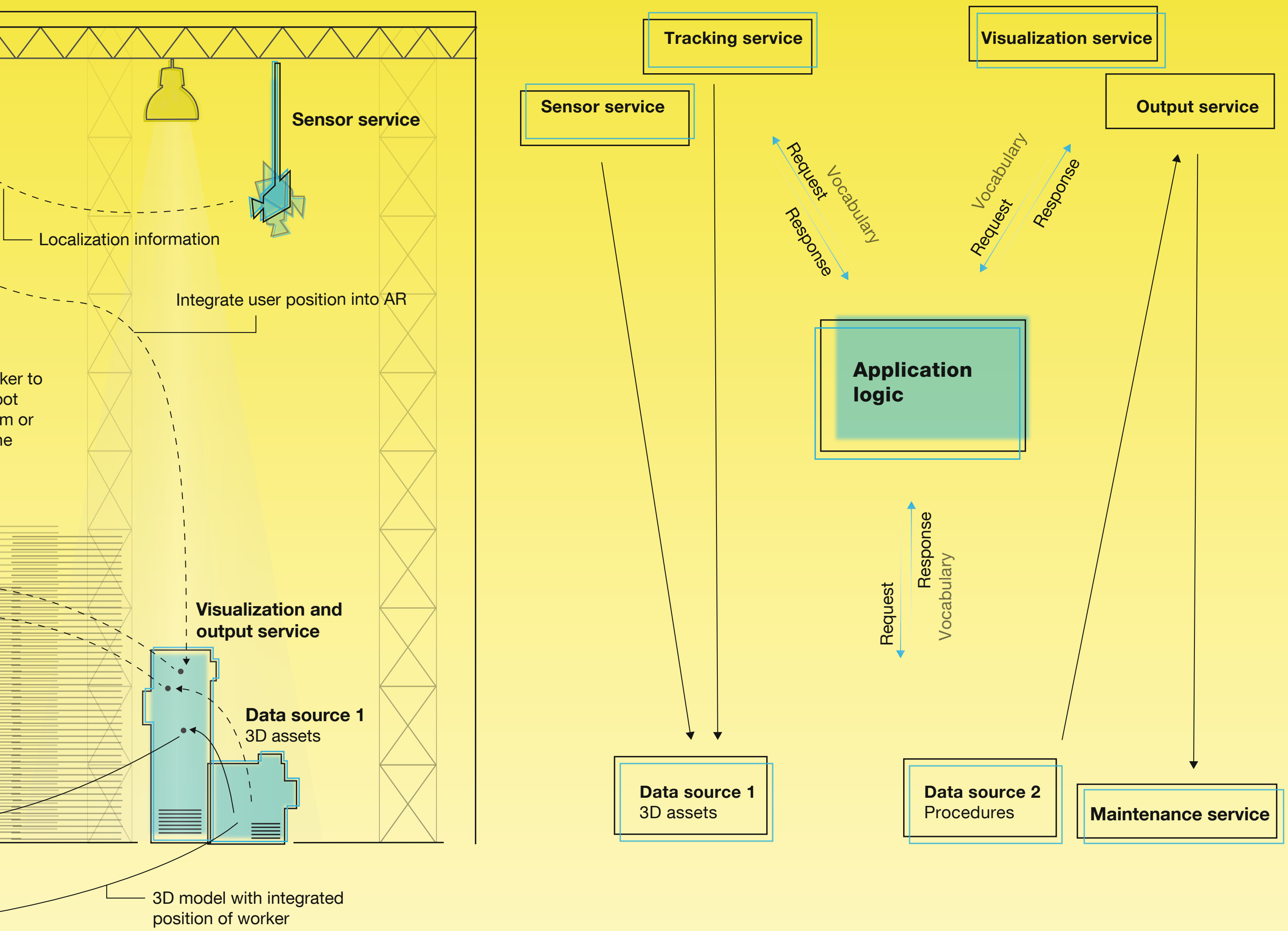
An open reference architecture based on Web technologies for rapid and flexible implementation of AR applications (right) – shown here in a maintenance scenario (left). Centrally provisioned services support typical functions such as user tracking, which maps the user in relation to other objects in the vicinity, and sensing, which uses data from cameras, thermometers and microphones.

A sense of abstraction: reference architecture for AR applications

The use of AR in industry is gathering pace – in production planning, for instance, as well as for maintenance purposes. Another example is vehicle repair, where technicians might receive the exact information required for a specific vehicle by tablet, say, saving them the time and hassle of leafing through printed manuals.

To date, though, system environments for AR applications have generally been based on closed designs. This makes adding new functionality difficult and expensive. In addition, accessing third-party systems is complex, as data needs to be converted to do this. In the ARVIDA research project, funded by the German Federal Ministry of Education and Research (BMBF), Klinker and her team thus worked with partners in business and science to develop a reference architecture for AR applications. The abbreviation stands for the German project name, which translates as “Applied reference architecture for virtual services and applications.” In contrast to pre-programmed and inflexible monolithic applications, this architecture uses abstraction to describe common features and thus enable the design of overarching development systems. To do this, the researchers analyzed the similarities across several applications in industrial product development and production planning.

One application, for instance, was designed to improve vehicle ergonomics. As a first step, the researchers used a tracking system to record the motion sequences of several drivers.



Alongside concrete information such as 3D system models and manuals/instructions, data services also offer data models and simulations to forecast the outcomes of specific actions. Visualization and output services present the information in optimized format on the user's device or on appropriate displays in their surroundings. These services employ a defined vocabulary to present their services to ensure they can be used across different AR applications.

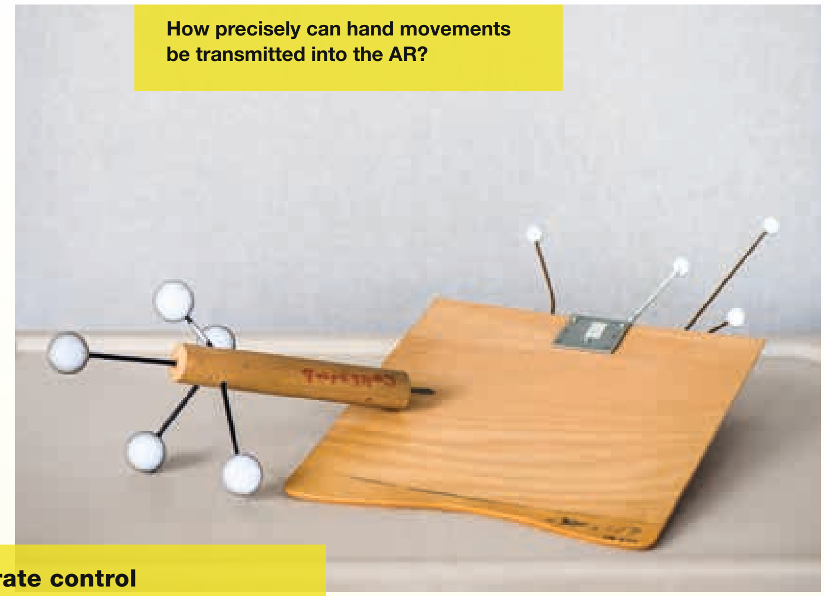
Graphics: ediundsepp (source: TUM)

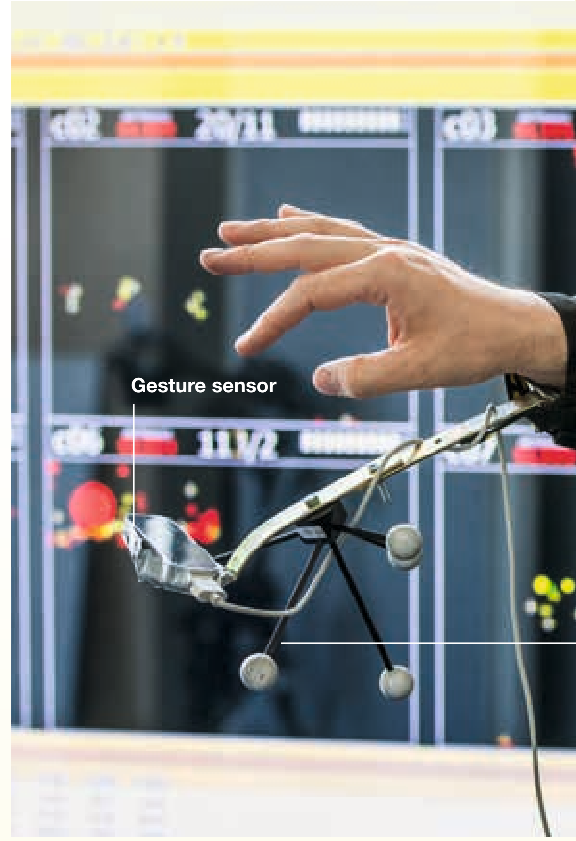
They then used this to define basic movements, which they imported into a virtual vehicle environment. From this movement pool, they could now create new motion patterns without having to track them again – thus, essentially from the lab. The researchers also standardized the process to extend beyond this specific use case, for use in other applications – such as improving the installation of vehicle parts. Instead of motion sequences, this involves tracking components and integrating them in a virtual vehicle. Checks can then be carried out even before the components are manufactured, ensuring they are fully compatible and identifying ways to improve their assembly.

For the reference architecture, Klinker and the ARVIDA team held intensive discussions to analyze the recurring methods across the various applications. From this, they put together and tested application packages, thus deriving standards from individual use cases. "It's all about choosing a level of abstraction that makes sense such that you can capture the essence," summarizes Klinker. After three years of research, the outcome in 2016 was an open reference architecture based on established Web technologies. This gives product developers and production planners a tool kit they can use to build new AR applications faster, more flexibly, and more cost-effectively than ever. ▷

Input modes for VR/AR

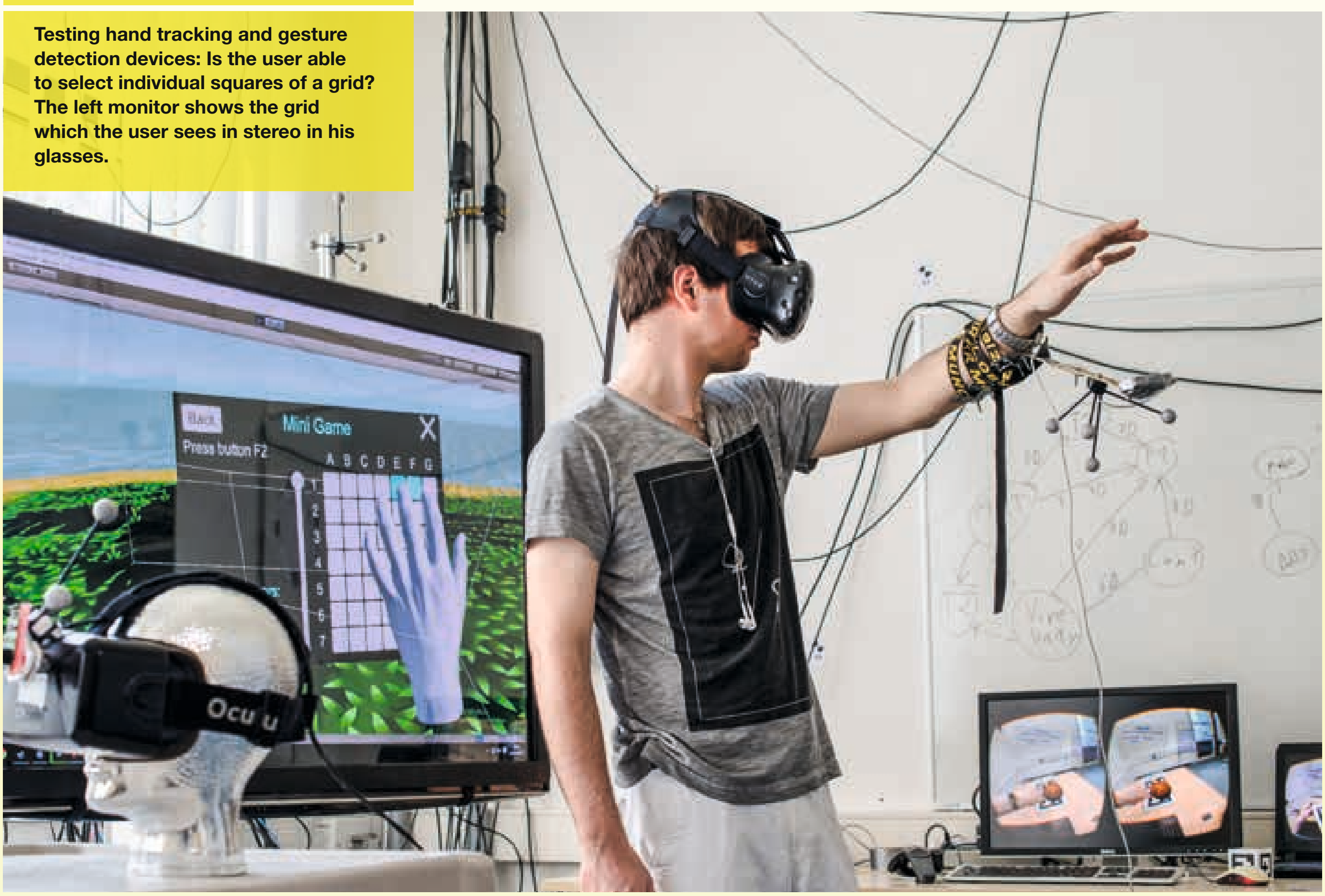
How precisely can hand movements be transmitted into the AR?

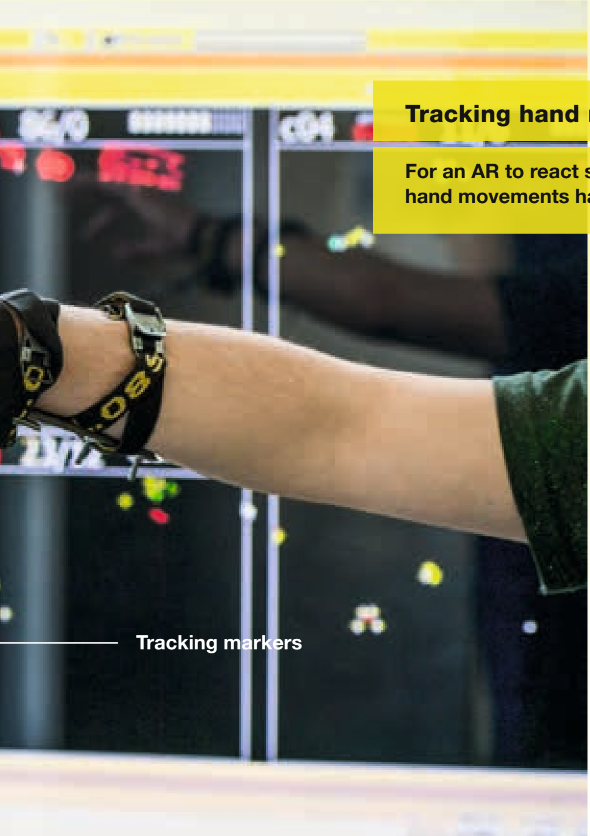




Accurate control

Testing hand tracking and gesture detection devices: Is the user able to select individual squares of a grid? The left monitor shows the grid which the user sees in stereo in his glasses.





Tracking hand movements and gestures

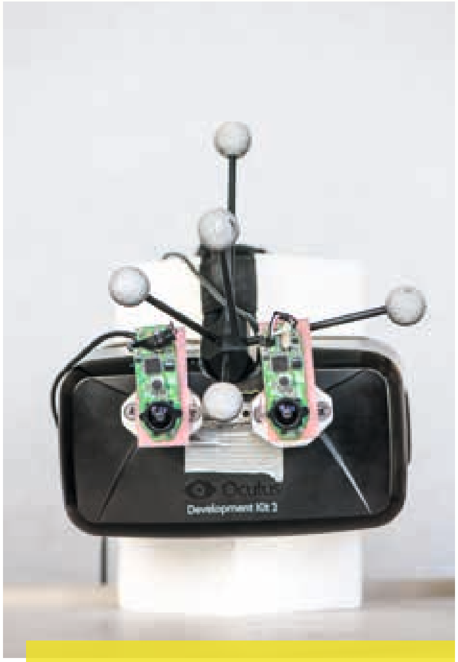
For an AR to react smoothly to the user's actions, gestures and hand movements have to be determined very accurately.

Staying in touch with the real world

See-through AR headsets pick up the user's view with an integrated camera and display augmented information directly on the glasses.

Eye tracking

AR systems that "know" where the user is looking are able to display information precisely in the right spot.



VR becomes AR

The real world recorded by the camera is displayed inside this VR headset. Additional markers provide extra options to track the user's position and head movements.

Picture credit: Eckert

Augmented reality allows people to remain present in the real world instead of shutting it out.

Prof. Gudrun Klinker

It is no surprise that Gudrun Klinker opted to pursue her research in augmented rather than virtual reality: VR would have been far too one-directional for the professor, who now leads the Augmented Reality research group at TUM. AR links the physical to the virtual world, connecting hard facts with creativity – a juxtaposition that ideally suits her personality.
At school, Klinker was equally interested in sciences and languages – as reflected in her choice to focus particularly on mathematics and French. When selecting her degree course, she got hold of a study guide for computer science and the description of the subject as a mixture of math, logic, language and philosophy immediately caught her attention. "The core focus was not on programming, but on handling information and structuring it systematically. This remains the essence of it today – and continues to fascinate me now as it did then." Although the beginning of her career – back in the days of punch cards – mainly entailed data processing, her focus was always less on the device and more on the information in its own right.
Klinker specialized in image processing right from the start. Following her Informatics studies in Erlangen and Hamburg, Germany, she moved to the US, where she obtained her doctorate from Carnegie Mellon University in Pittsburgh before starting work with the Digital Equipment Corporation at its Cambridge Research Lab. The 1980s were a pioneering period for computer graphics and virtual and augmented reality. This was also when she saw the first CAVE at a trade fair – a space for projecting an immersive, virtual 3D environment.
After eleven years – now married and a mother of two – Klinker returned to Germany, where she teaches at TUM's Department of Informatics as Professor of Augmented Reality. Here, she has been instrumental in establishing the "Informatics: Game Engineering" degree program, which has attracted 150 to 200 students per semester since 2011. As she emphasizes: "Given our expertise as a technical university, we designed the program with a highly technical slant. Our aim is to give students in-depth competence on the technical aspects of games, while also incorporating enough interdisciplinary insights to ensure they have an open mindset later on towards design, artistic and game production aspects." Ultimately, interdisciplinary collaboration is a key success factor for innovation – and, of course, no-one is more aware of that than Gudrun Klinker, as she looks ahead at so many different avenues.

A compelling experience – but there are risks

AR has entered the mainstream beyond industry – recently boosted by the hit game Pokémon Go, launched in 2016. Here, virtual fantasy creatures hide in various places, and a gamer only sees them when he or she is nearby. Then, the figures show up on the smartphone display integrated into the user's real surroundings. And that, in a nutshell, explains the appeal of augmented as opposed to virtual reality (VR): AR allows people to remain present in the real world instead of shutting it out. "A Pokémon apparently standing on my own coffee table in my actual surroundings has a much greater emotional effect on me than if I were to see it in an unknown setting," Klinker explains.
At the same time, the compelling nature of AR can actually make it hazardous when users lose sight of the world around them. This is already an issue with pedestrians who fail to notice red lights because they are staring at their smartphones – now a regular occurrence on our streets. The German city of Augsburg has already reacted by installing ground lights aimed at preventing accidents when people are staring downwards onto their phones – an idea that has attracted major interest worldwide. Driver assistance systems are another example here. Whether their purpose is navigation, communication or entertainment – these systems must be laid out in a way that avoids distracting drivers. And we have to know when to step in. "It's the same as with back-seat drivers – some people would be well advised to hold their tongue," observes Klinker drily. The key question is: how much virtual information can someone absorb without losing concentration on their actual surroundings? Or, in short: how much distraction can a person take?

Keeping users keen

As part of this research interest, Gudrun Klinker is currently working on the use of eye tracking in head-mounted displays. This involves recording and evaluating eye positions and movements of people wearing head-mounted displays. "We are improving eye tracking methods and trying to establish as precisely as possible where the user's eyes are positioned behind the glasses and what they are looking at," explains Klinker. This is essential for the glasses to display information in exactly the right place to overlay the physical objects it relates to. And that has significant consequences for the user. Tracking a user's eyes enables them to control a program without a mouse, for instance – and let it know what they find interesting. ▷

Picture credit: Eckert

"This then raises the question: when are users looking for this type of added information and when are they just moving their eyes for no particular reason?", specifies Klinker. For that reason, AR research involves not only computer scientists, but also educators, psychologists and methodologists, to determine how best to convey the information. And this directly leads to further questions: How can someone's interest be aroused? And how can they be motivated to do something? "The nature of Homo ludens (Latin for "playing human") is to develop new things by experimenting; through playful exploration. So it's a matter of fueling this playful interest," Klinker explains.

Here, she mentions storytelling and gamification – two key tools in this area. And researchers have long since been working on other AR devices besides the glasses. "The limited field of view means that glasses detract quite a bit from the reality of the experience, so you have to "bend" your senses to compensate. That's why everyday objects hold great promise for AR." Klinker is currently working with nutritional scientists and doctors to develop a drinking glass for older people, for example. This intelligent glass registers how much someone has drunk and gives them playful reminders to drink more if need be – for instance, by ceasing to show photos of their grandchildren on its integrated display. Klinker is also looking forward to further interdisciplinary research: "Now that the technology is so far advanced, we can focus on the psychological element too – which also means bringing in experts from other fields who were previously deterred by all the bits and bytes flying around."

Gitta Rohling

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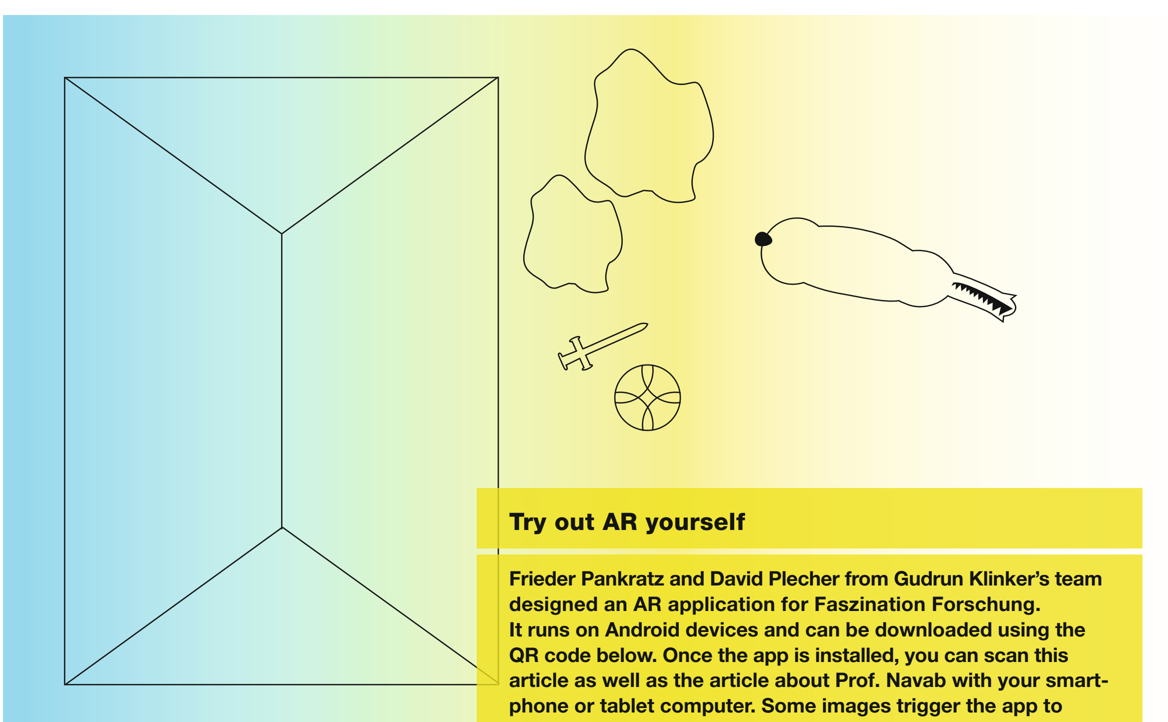

Try out AR yourself

Frieder Pankratz and David Plecher from Gudrun Klinker's team designed an AR application for Faszination Forschung. It runs on Android devices and can be downloaded using the QR code below. Once the app is installed, you can scan this article as well as the article about Prof. Navab with your smartphone or tablet computer. Some images trigger the app to show additional information, overlaid in 3D above the images.

Graphics: ediundsepp