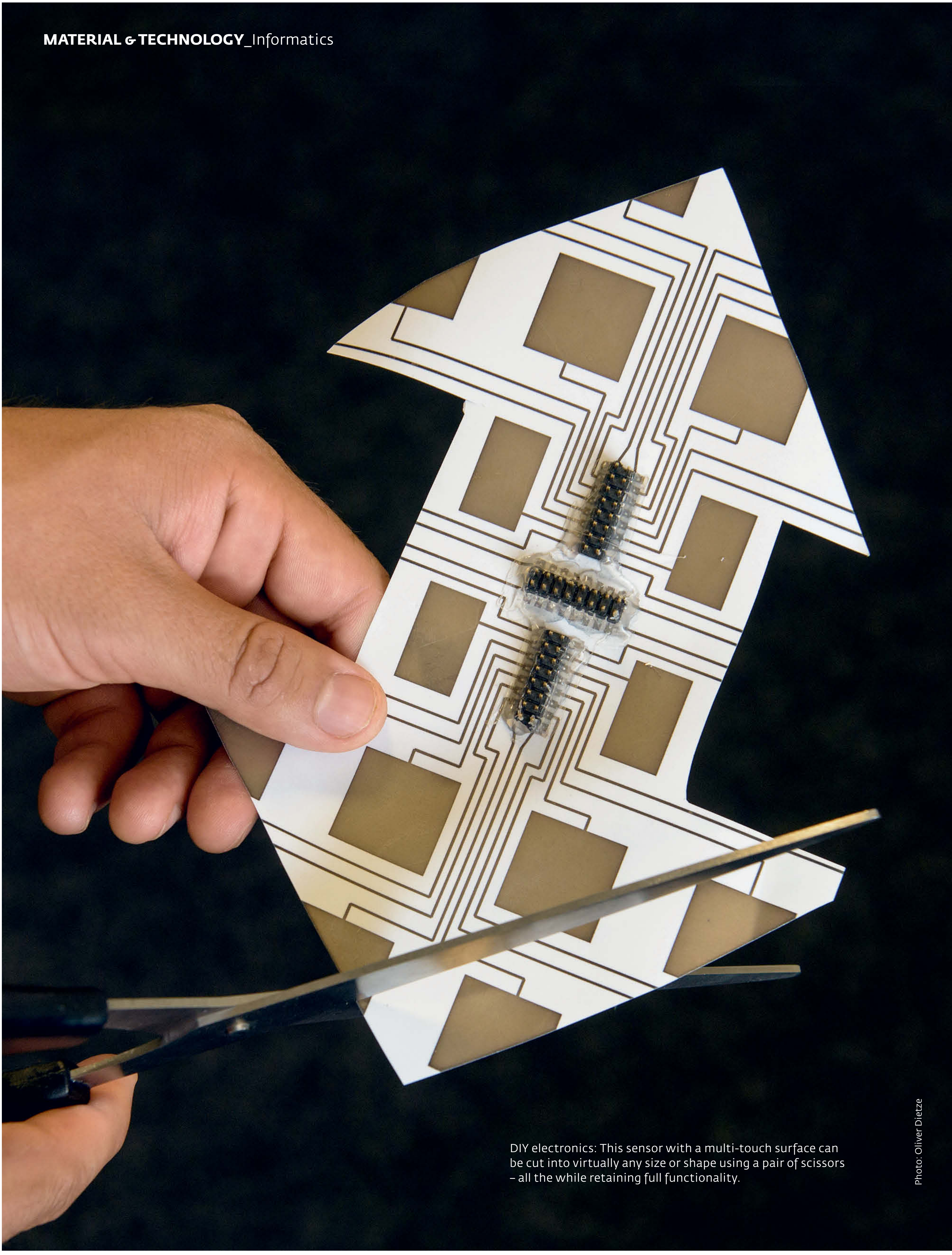


DIY electronics: This sensor with a multi-touch surface can be cut into virtually any size or shape using a pair of scissors – all the while retaining full functionality.

Photo: Oliver Dietze

Displays
Straight from the Printer

His research looks hip and colorful. The prototypes are made from wood, paper and plastic. Cut, printed or pressed. But there's more to them than meets the eye: **Jürgen Steimle** and his team at the **Max Planck Institute for Informatics** and at **Saarland University** in Saarbrücken are concentrating their efforts on a fully interconnected world in which, for example, computing devices are activated via skin-worn sensors.

TEXT **GORDON BOLDUAN**

Taped to the office wall is a science poster informing readers about miniature screens on fingernails. Mounted next to it is a pegboard with screwdrivers, pliers and even hammers. Suspended from the ceiling is a camera system composed of aluminum insertion rails and six infrared cameras, and across the rough gray carpet, numerous electric cables snake their way around stacks of transparent plastic boxes.

One of the tables is covered with myriad notepads surrounding a black keyboard and a flat-screen monitor. At the very center stands the balsa wood prototype of an apparatus, back to back with a structure consisting of acrylic glass, micro-controllers, circuit boards and colorful plastic wires.

These are the kinds of contrasts that Jürgen Steimle brings together, not only in his laboratory, but also in his research. The sign on the door reads "Lab Space." Steimle set up this area for his students and doctoral candidates at Saarland University's Cluster of Excellence on Multimodal Computing and Interaction, where he heads the independent research group on Embodied Interaction. He also conducts research at the Max Planck Institute for Informatics, which is within walking distance of the university building.

COMMUNICATION IN AN INTERACTIVE WORLD

Jürgen Steimle and his students are convinced that, a few years from now, every object will contain a computer. That's why their focus lies on the principles that make it possible to work and communicate with the hidden electronic components in such a completely interactive world.

Mobile terminals with impractical designs not only irritate users in day-to-day life – they also become the object of ridicule. Social media platforms such as Facebook are full of popular posts predicting how clunky smartphones or the Apple Watch would look if engineers had designed them a decade ago with the technology available to them at that time.

What the scoffers fail to account for, however, is that even the most modern technological possibilities are often far from ideal for users. "Today, if I want to activate my smartwatch via touch input, I have only a small display available, and most of it will be obscured by my fingers," explains Jürgen Steimle, referring to what his colleagues call the "big thumb problem."

The 35-year-old computer scientist studies what happens when product development focuses solely on what is technologically feasible, and seeks to tackle the problems that arise as a result by nipping them in the bud: "The shape of devices must not be restricted to the limits of today's technology! Only then can we develop customized forms of interaction that can be integrated into items and objects that we use in our real world in so many different ways," explains Steimle. One of the tools he uses for this purpose is user studies. His goal is to develop the modes of interaction of the future.

BASIC RESEARCH ON TWO LEVELS

"Printed electronics is the key technology for us right now. It allows us to develop electronic components that have entirely new properties and are ultrathin, shapeable and even stretchable. They no longer bear any resemblance to conventional computers," says Steimle. By adopting this approach, he conducts basic research on two levels at the same time: based on systematic surveys, he designs completely new modes of interaction; and he implements the latter using technologies that themselves are still in the development phase.

A huge shelf divides the "Lab Space" into two parts, with the right half being reserved for the workbenches and electronic equipment. The members of Steimle's group – three doctoral students and two master's candidates – have gathered in the left half of the room. They're sitting at two tables that were pushed together in front of a wall, and stuck to that wall are a number of round, yellow cue cards with handwritten notes; on one of the tables, Steimle placed a workshop kit filled with colored markers and pieces of construction paper cut to size.

Steimle sits at the table with his back facing the window, which offers a view of Saarbrücken's informatics campus, including the Max Planck Institute for Software Systems, the Intel Visual Computing Institute and the Center for Bioinformatics.

Using creative techniques and the right tools to find answers to questions in a group setting is a method that the researcher became well acquainted with during his time at the Massachusetts Institute of Technology's Media Lab,


Photo: Oliver Dietze

Working on the future: The research conducted by Jürgen Steimle (left) and his team focuses on developing electronic components with entirely new properties. This includes the iSkin sensor, which detects touch input on the user's skin. The sticker pictured on the right was designed for the forearm and is used to activate a digital music player. The researchers integrated a number of touch keys – for "Play/Pause," "Fast Forward," "Rewind" and "Volume."

Photo: Saarland University, Embodied Interaction Group

where he worked as a visiting assistant professor in 2012 and 2013. Steimle's career began in 2009 when he published his doctoral dissertation, which the German Informatics Society (GI) distinguished as being the best in the German-speaking countries.

Since 2013, Steimle has been working as an independent head of a junior research group at the Cluster of Excellence in Saarbrücken. The Cluster of Excellence introduced this position to grant its currently 15 researchers the freedom to set up or expand their own groups and define their own agenda. In order to ensure that they have the scientific liberties they require for their work, each team receives a budget. Furthermore, all heads of junior research groups are allowed to supervise their own doctoral students.

Daniel Gröger is the newest member of Steimle's team. Since October of last year, the doctoral student has been working on a completely new three-dimensional printing method. So new, in fact, that Steimle swears his students to secrecy and urges them to refrain from broadcasting the news to the international tech-blogger community via Facebook or Twitter.

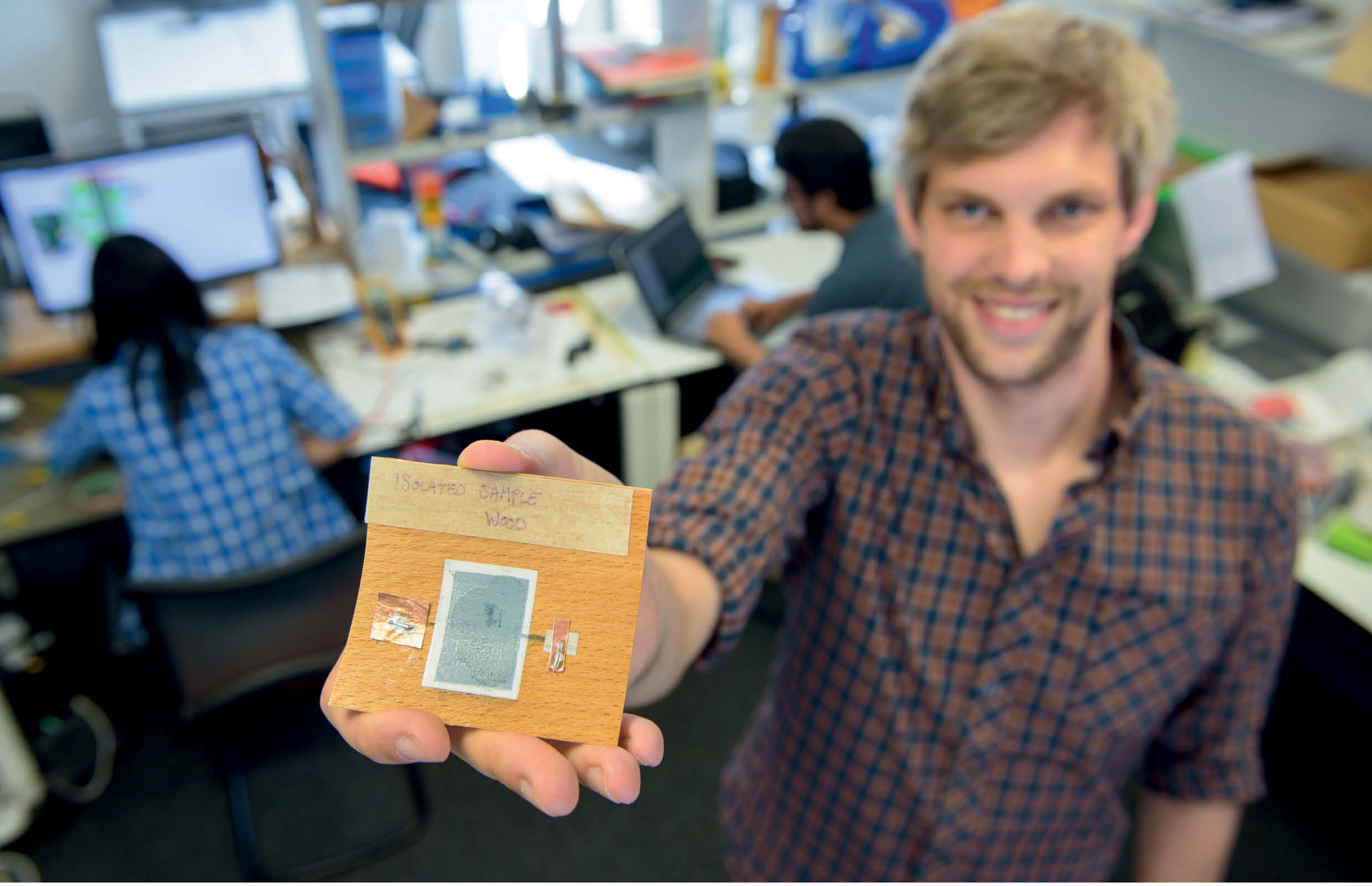
AN ELASTIC SENSOR WORN ON THE SKIN

Speaking in English and using short, precise sentences, Jürgen Steimle outlines his expectations regarding the upcoming brainstorming session. He's looking for applications for the components that can already be printed in three dimensions. The group's task is now to jointly come up with ideas. Everyone grabs one of the colored, rectangular cue cards. For the next few minutes, the only sound heard in the room is that of markers scribbling away.

However, in the case of the most recent project, iSkin, with which Steimle's doctoral student Martin Weigel is currently causing a stir around the globe, the researchers opted for a different approach. "We made a conscious decision not to start out with the technology, but to use the skin as a natural medium instead," says Steimle. Skin has a larger surface area than any smartwatch. They conducted a survey among 22 participants – 25 years old on average – and asked them what kinds of actions they would perform on their skin if it could serve as an input sensor for mobile terminals.

"Interestingly enough, an additional dimension came to light: expressive interaction. When physically interacting with their skin, the users didn't just touch it – they also pressed it firmly, pulled it or even twisted it," says Steimle. Based on these insights, the researchers developed a prototype of a sensor.

"It is the first elastic, skin-worn sensor that can be used to interact with computing devices," says Steimle. The elasticity posed a considerable challenge, he recalls, because it requires conductors that don't break when stretched. To solve this problem, the computer scientists from Saarbrücken collaborated with materials scientists from Carnegie Mellon University in the US. The latter had devised a method of combining different types of silicone that would be suitable for this kind of sensor. >



Prototypes: Doctoral student Simon Olberding holds up a thin, light-emitting display that the scientists printed onto wood using the PrintScreen technique. The display detects the user's touch input through the veneer. This method was also used to enhance a conventional Swatch wristwatch by printing the display onto the band with symbols that alert the user – for example when a new e-mail has been received.

Photos: Oliver Dietze (top), Saarland University, Embodied Interaction Group (bottom)

Furthermore, silicone is a skin-friendly material that can easily be affixed to the skin using a medical adhesive. Pressing a particular part of the sticker would allow you to take an incoming phone call or adjust the volume of your headphones, for example.

AESTHETICS MATTER, TOO

Yet the scientists from Saarbrücken didn't content themselves with merely solving the device's functionality issues – not by a long shot. "Our goal was to create a sensor that truly takes a person's individual sense of aesthetics into account. This means it needed to look good and make a visual statement that the respective wearer can identify with," says Steimle.

For that reason, the researchers also developed procedures that allow designers to turn lines, shapes and silhouettes into iSkin sensors according to their own personal taste. The result: when placed on the skin, the semi-transparent control interfaces look like artistic tattoos and no longer bear any resemblance to conventional control elements.

Back in the brainstorming session, the members of Steimle's team are now taking turns presenting their ideas by holding up their cue cards to show the drawing and explaining it in a nutshell. Next, the cards are stacked at the center of the table and everyone takes a few to add their own notes and then hand them to the person on their right. The cards are passed around the table for the next 15 minutes. Many of them make Steimle smile, and some of them even prompt him to grab a new card so he can add additional thoughts in small letters using a broad marker.

This method of continuous reflection is also evident in his projects. Another major goal that Steimle's group has set itself is devising a simple method that would allow average users to adapt technology to their own personal needs. Steimle and his doctoral student Simon Olberding have already come up with a solution to this problem by building a prototype of their project called PrintScreen. The prototype is set up on a separate table for demonstration purposes.

A postcard depicting a vintage automobile serves as an example. When a button is pressed, the rear axle and steering column light up in the same color. This is made possible by two segments of a flexible display that have the same shape as the car parts. Steimle's group printed the display using a conventional inkjet printer. The printable screen is electroluminescent: it emits light when an electric voltage is applied.

Until now, it was possible to produce displays only in large series, but not for individual users. The researchers in Saarbrücken have changed that. The process they developed works as follows: Using a software program such as Microsoft Word or PowerPoint, the user designs a digital template of his or her customized display. They can now print the template using one of two methods devised by the researchers. This is done using the inkjet or silkscreen printing technique. In both cases, the ink contains conductive materials.

Although these techniques may have different strengths and weaknesses, they can be carried out by a single person in anywhere from a few minutes to four hours. The result: displays that have a relatively high resolution and are only 0.1 millimeters thick. Printing an A4-sized sheet of paper costs around 20 euros; the most expensive element here is the special ink.

And it gets even better: due to the fact that these techniques can also be used to print on such materials as paper, plastics, leather, ceramics, stone, metal and wood, users can create all sorts of two- and even three-dimensional shapes. According to the researchers, even touch-sensitive displays can be printed in this manner, thus opening up this technology to a broad range of possible applications.

Thanks to these techniques, displays can be integrated into pretty much any everyday item – not just paper objects, but also furniture and home furnishings, for example, or bags and wearable accessories. One possible application would be to use this technology to enhance the band of a wristwatch so that it lights up when the user receives a text message. "And if we now combine our method with three-dimensional printing, we would be able to print three-dimensional objects that display information and react to touch input," says Jürgen Steimle.

RELAXING WITH A CELLO SUITE BY BACH

In the meantime, the cards being passed around in the brainstorming session are now orange – the group already used up the green stack. Yet even the luxury of working with a professional workshop kit can't compensate for bad handwriting. Instead of "wearables" – computing devices worn by the user – Steimle reads out "werewolves" and gives everyone at the table an incredulous stare. The team bursts into laughter.

Twenty minutes later, the last person in the group snaps the cap back onto the tip of their marker. The students push the cards toward the center of the table, and every single card is now discussed. The brainstorming session brings forth keywords such as "personalized smartphone cases," "interactive rings" and "devices worn on the body." At the end of the session, Daniel Gröger holds a big batch of cards in his hands and uses his thumb to flick through them like banknotes.

A few hours later, Jürgen Steimle is sitting in his office, albeit in front of his desk rather than behind it. He has placed another chair in front of him, and propped up against the backrest is a yellow book of sheet music. Steimle keeps his eyes glued to the notes while his left hand holds the neck of a cello and his right hand lets the bow glide across the strings. As he plays Bach's Cello Suite No. 1, he is completely immersed in the music. Back in his days as a student in Freiburg, Steimle made a living as a cellist, and he performed in Russia and France as a member of the Academic Orchestra. Nowadays, the music helps him relax after a busy day of work.

Steimle scratches, hammers, plucks, strokes. He coaxes both the lowest and the highest notes out of his instrument before putting down his bow for a minute: "It's a relatively simple tool, yet you can use it to create a highly complex world. It's this contrast that I find so fascinating – also in my research." ◂

TO THE POINT

- **Our world is becoming increasingly interconnected. Researchers predict that virtually every object will contain a computer in the near future.**
- **Printed electronics are currently regarded as being a key technology. Thanks to these components, scientists can develop computing devices that boast entirely new properties and are ultra-thin, shapeable and even stretchable.**
- **Jürgen Steimle and his team study the principles of working and communicating with these embedded computers.**
- **The scientists are researching a new method for printing personalized computing devices, for example. In another project, they focus on human skin as an input sensor for mobile terminals.**