Crafting prostheses with form, function, and flair

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Carefully contracting the muscles in his forearm, Maximilian Mahal labored as he picked up the drinking glass and set it back on the table. Maneuvering the tumbler with his own hand would have been easier. But on this particular day last December, Mahal and his classmates were at a digital fabrication laboratory in Berlin, learning to grab objects with a prosthetic arm, despite having all their own limbs intact. He struggled, to say the least.

Amputees struggle as well. Adapting to prostheses has such a steep learning curve that many shun state-of-the-art devices and choose skin-colored limbs that function as little more than a stump. A group of engineers and artists recently came together to try to find a way forward.

Scientists and engineers are good at making things and solving problems, yet they may not excel at fitting their creations into an evolving culture, says Chuck Polta, a research and development director at the German prosthetics company Ottobock (www.ottobock.com/en/). Polta wondered if he could enlist the creative firepower of the arts community. "Artists and designers often have a better sense of how technologies can be applied in ways to have a more meaningful impact," he says.

A collaboration began to take shape. Polta reached out to Berlin's Weißensee Academy of Art (www.kh-berlin.de/) and Fab Lab (https://fablab.berlin/en/), an open digital fabrication studio. Their conversations spawned a new university course, "Artificial Skins and Bones" (https://skinsandbones.de/). The class challenged Mahal and others at Weißensee, mostly master's students in product design, to consider nature's patterns and functions and apply them to the design of artificial bodies. With input from engineers and technicians, the students explored topics ranging from the language of sensation to the aesthetics of natural bodies. Several teams proposed innovative ways to approach the design of artificial limbs. At the Ars Electronica Festival, held September 8–12 in Linz, Austria, students in the course shared one of two €20,000 STARTS prizes, a competition the European Commission launched this spring to honor innovative projects that promote collaboration between science, technology, and the arts (1).

The Skins and Bones project exemplifies how an interdisciplinary collaborative environment of scientists, artists, and designers can bear fruit, says Victoria Vesna, an artist and professor at the University of California at Los Angeles. "When this kind of diverse group puts their heads together to solve a problem, solutions are often unexpected and innovative," says Vesna, who served on the STARTS judging panel and directs the University of California, Los Angeles's Art|Sci center.

Master's student Maximilian Mahal, working at Fab Lab in Berlin, tries out a prototype prosthetic-aid for computer users, called Shortcut, which employs wireless signals from amputee limbs to manipulate computer applications. Image courtesy of Lucas Rex, David Kaltenbach, and Maximilian Mahal.

Engineering Replacements

Although applying an artist's mindset to engineering projects can be transformative, it isn't easy, even for those with backgrounds in both. Nina Rossow, a master's student in product design, came to the Skins and Bones course having had four years of classes in drawing, 3D modeling, prototyping, and other design and art essentials. Before that, she'd earned a bachelor's degree in physical engineering and worked four years as an engineer.

Rossow recognized the different mindsets at work. Engineers often analyze structures and movements to define some optimum parameter, such as stability, speed, or efficiency. In doing so, they seek out a single solution. But designers, Rossow says, see a wide field of possibilities: initial inquiries are often naïve brainstorms. The Skins and Bones project was an adjustment. "It took a while to say goodbye to my inner engineer and be free enough to become a designer," she says.

To kick off the course, students got an overview on prostheses from Ottobock engineers. They also heard from amputees, including an armless soccer player whose visit made an impression on Mahal. The athlete had turned down prosthetic limbs because "they couldn't perform to his demands," Mahal recalls. "He was very proud of being independent and managing his life."

Working on their projects alone or in teams of two or three, the students consulted with technicians and

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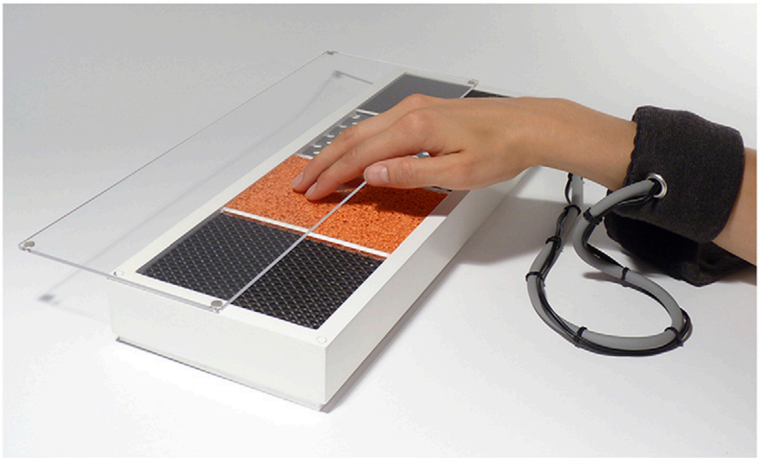
engineers for feedback. Which parts of the prototype were critical? Was the scope too costly or complicated? "If it required a half-million-dollar piece of equipment that no one had access to, that wasn't going to be realized within the semester," says Polta, who helped arrange a class visit to the company's corporate headquarters in Duderstadt, a 2.5-hour train ride from Berlin. The goal was for each team to build a working prototype with €200–€300 of materials. Some projects were concept-heavy, whereas others focused more on the technology, says Wolf Jeschonnek, one of the instructors.

One team designed intelligent textiles with surface structures that function something like the pores in human skin, opening or contracting to control moisture levels. Other students were inspired by an octopus' ability to change its skin color purposefully to regulate its temperature or evade predators. The students fitted color-changing fabric with muscle sensors to create a skin-like material with hues and patterns an amputee could consciously control using muscle activity.

In one of the more high-concept projects, a student created lattice structures using 3D printing, layering on materials in a way similar to the natural growth process of human tissues. That project didn't get as far as the student had hoped because of time constraints. Each round of 3D printing took three weeks. A different material might have helped, but the instructors tried hard to facilitate work flow without imposing their own ideas. "Making mistakes and learning from them is part of the process," says Jeschonnek.



When a user touches the glass of this prosthetic aid, the armband conveys tactile features of the material below in the form of mechanical signals, such as pulses or vibrations. Image courtesy of Nina Rossow.

Useful Feedback

But some high-tech brainstorms have potential. Rossow had long been fascinated by the sense of touch. Amputees, using their prostheses, can't tell if a surface is hot or cold, soft or hard; artificial limbs don't provide that kind of feedback. Rossow wondered if it might be possible to generate tactile feedback through other parts of the body.

She created an armband that conveys a material's properties—such as roughness or smoothness—as different kinds of mechanical signals, such as short pulses or vibrations. Someday Rossow hopes to transform words or short sentences into mechanical patterns the skin can detect. Because this kind of tactile communication doesn't interfere with vision or hearing, it could help deaf or blind people, or anyone who needs a different means of communication in dark, noisy places, Rossow says.

Other projects had more potentially practical relevance for amputees. One team developed a learning aid for lower-limb amputees using shin prostheses. The device translates walking motion into acoustic feedback on a smartphone to reinforce proper posture and foot placement.

For Mahal and his teammates, David Kaltenbach and Lucas Rex, trying out their so-called myoelectric prosthetic—and seeing how cumbersome it was to pick up a glass—was eye-opening. Myoelectric prosthetics detect muscle activity in the missing limb and use those "phantom" signals to power electric motors in the artificial hand. Because fine-motor readouts are difficult, making finger movements is impossible, or at best excruciating. Some manage to drag a computer mouse with their prostheses, but "as soon as you want to scroll or make a left click or right click, it's all over," Mahal says. To use a keyboard, amputees may have to use their artificial hand to grab a pencil and poke keys one by one. Rather than making their lives easier, the prosthesis makes them more disabled, Mahal says. And yet, amputees, he notes, often take on office jobs, making base-level computer skills important.

Flummoxed and frustrated by the ineffectiveness of arm prostheses, the students stumbled on a key insight: rather than trying to use the "phantom" signals for a complex series of physical movements, why not hijack those signals and take them straight to the computer to do something specific, like click a mouse or scroll through a website? The team bought a $200 myoelectric gamer bracelet, hacked a computer mouse to get an optical sensor, then added a Bluetooth wireless connection. The result was Shortcut, a digital wristband that is worn on a prosthesis and connects wirelessly to myosensors on the arm and to the computer, bypassing the complex sequence of motor signals required for even the click of mouse (www.digital-prosthesis.de/). The prototype showed that a few tweaks to existing technology could transform how amputees function in the digital world.

The students' creations inspired Ottobock product developers, says Polta. "Their work challenges our assumption," he says, "that clever ideas take a big a budget and lots of resources to develop." Mahal and his teammates hope the experience was more than just an exercise in collaboration. To refine their design, they now plan to develop a more robust and reliable Shortcut prototype that they'll put through intensive testing with amputees.

1 Hieslmair M (2016) STARTS Prize to "Artificial Skins and Bones." Available at www.aec.at/aeblog/en/2016/06/23/artificial-skins-and-bones/. Accessed October 7, 2016.