Picture credit: Andreas Heddergott

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www.ar.tum.de/en/hk/associate-professorship
www.3fstudio.de

Many Features, One Material, One Process

Moritz Mungenast designs recyclable facades. For his research doctorate, the architect studied how 3D-printed facades can simplify and improve the traditional method used to construct them.

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Viele Funktionen, ein Material, ein Prozess

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Digitalisierung in der Architektur wirkte sich bislang auf den Entwurfsprozess aus. Mit der Entwicklung immer besserer 3D-Drucker, die immer größere Bauteile im Maßstab 1:1 herstellen können, ergibt sich ein neues Potenzial. Dies systematisch zu erforschen, ist Thema der Promotion „3D Printed Future Facade“ von Dr. Moritz Mungenast. Als wissenschaftlicher Mitarbeiter an der Professur für Entwerfen und Gebäudehülle der TUM untersuchte er Möglichkeiten der Additiven Fertigung, wie sie sich mit dem 3D-Druck erstmals bieten. Konkret entwarf er Funktionsgeometrien und erprobte die Funktionsintegration von 3D-gedruckten Fassadenelementen. Ein prototypisch realisiertes Element wurde auf seine optischen, thermischen und statischen Eigenschaften hin untersucht und einem Langzeittest auf der Solarstation der TUM unterzogen. Dabei zeigten sich die Möglichkeiten, wie man mit nur einem Material und in nur einem Prozess komplexe Anforderungen technischer und gestalterischer Art individuell erfüllen kann. □

Dr. Moritz Mungenast

Born in 1974, Moritz Mungenast studied architecture in Kaiserslautern, Lausanne, and Barcelona, before completing his Diploma (equivalent to a Master's degree) at TUM in 2003. His career has included roles at Auer + Weber in Munich and Shigeru Ban in Paris. He was a research fellow at the Professorship of Building Design and Product Development at TUM in 2009 and has been based at the Associate Professorship of Architectural Design and Building Envelope and the Guest Professorship of Emerging Technologies since 2010. In 2014, he launched and led the "3d-printed envelopes" research initiative while continuing to work on his doctorate, which he completed in 2019. He co-founded the spin-off 3F Studio in 2018.

Dr. Mungenast, what's the basic idea behind your research project?

What I first asked myself was this: Can you use 3D printing to create a strong, functionally integrated facade that also happens to be recyclable? Taking the facade as an example, I demonstrate some of the advanced possibilities that 3D printing offers for 1:1 application in architecture. One priority is how to integrate various functions and features into the printed facade. This prompts more questions, such as: How should you design moving parts? For instance, what would a 3D-printed door look like if it could adapt to a free-form surface? As this is about architecture, design considerations also play a key role alongside technical ones.

What specific aspects did you have to deal with?

My thought process was: If you had a facade that was the perfect combination of computational design and 3D printing, what could it look like? The aim is to simplify the construction process and fill the gap in the digital chain between design and production without sacrificing performance. This requires devising completely new geometries for the structure to fulfill its functions – known as functional geometries. Faced with a raft of new possibilities, I had to pick out those that were suited to being part of a facade element. First of all, I used 3D-printed prototypes to investigate individual aspects such as insulation, sun protection, ventilation, acoustic distribution, and ease of movement – of a door, for example. After I'd analyzed my results, these features were combined into a single, functionally integrated component, which was then itself reviewed and optimized.

What did "functional integration" mean?

Facades are usually made up of several elements. There's the window, a sealed panel providing insulation, another element protecting against the sun, a further component ensuring ventilation, and so on. These individual components interact and, in so doing, perform various functions. Hence the idea to integrate these functions with the help of efficient geometry. The desired degree of comfort and convenience – such as you get from a building's insulation, lighting, ventilation, and the shadow it casts – is achieved using a single element made from a single material, which is manufactured in a single process step and is completely recyclable.

What can a 3D-printed facade do that conventional ones can't?

First and foremost, they need to do everything conventional facades can. But it's easier to tailor them to different locations and tweak their unique features. Plus they form part of a closed-loop material cycle. In other words, the facade is turned back into a facade, something that's still some way off being achieved in conventional construction. They also offer a wide range of design possibilities.

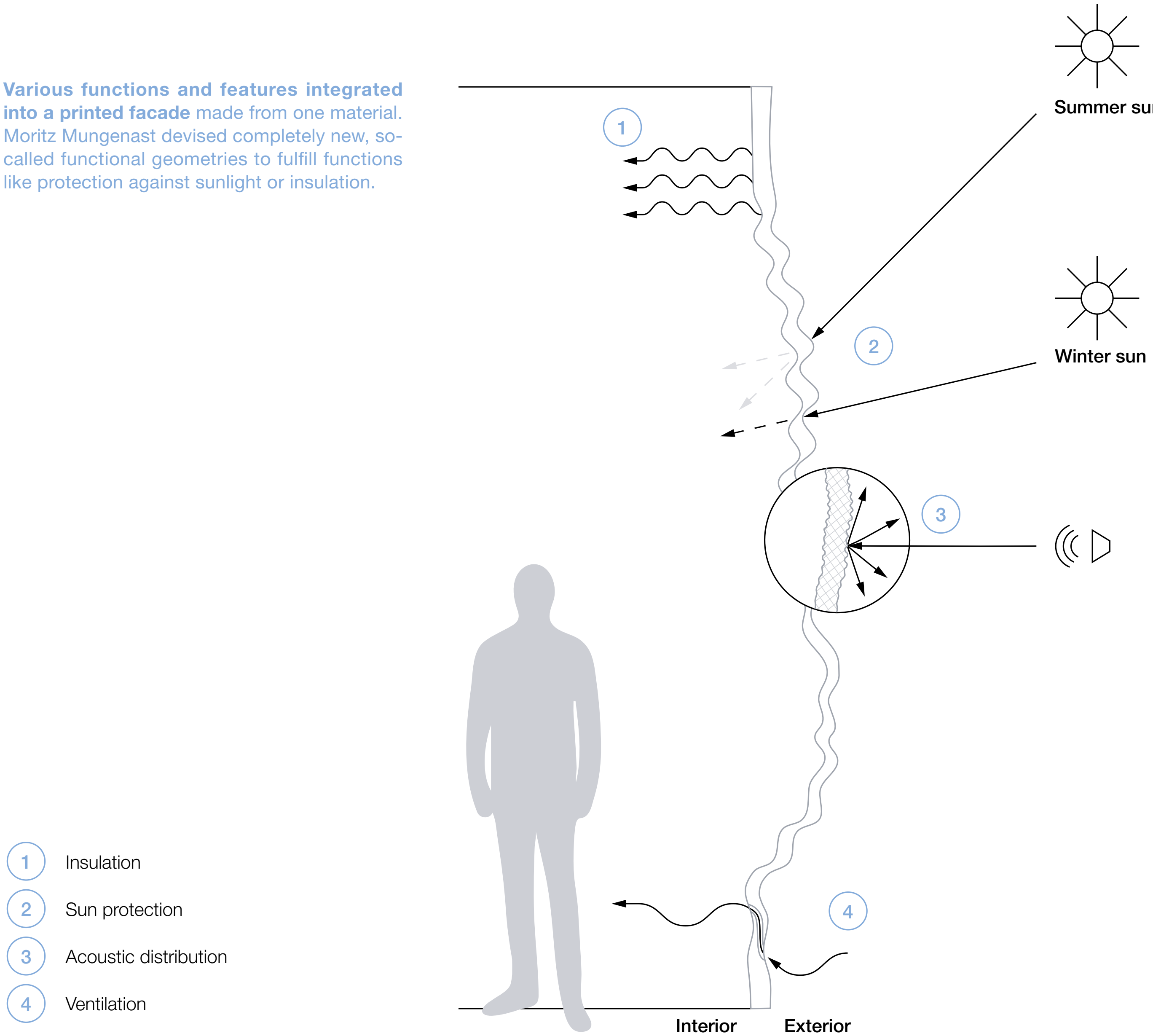
What problems did you have to solve to get where you wanted to be?

First of all, I had to decide what features I could reasonably achieve using a 3D printer, what parameters determine functional geometry, and how they can be combined in a single component. All of this I investigated as part of what I was teaching my students. After that, the biggest challenge remains the implementation – reproducing the geometries in plastic on a scale of 1:1. This process is just getting under way. 3D printers don't yet have the level of process reliability that would mean you only needed to press the button to achieve a consistent result. Melting the material, printing the design, and leaving it to cool down – these are all highly sensitive parameters that you need to monitor. And then there's the time element: Printing is still a very long-winded process. Even in the follow-on projects, however, tolerance ranges have been significantly improved and printing takes much less time. The technology is progressing extremely rapidly. ▷

3D printing of a facade element (ca. 80 x 90 cm) at the technical center of the TUM Department of Architecture. The printer is a large area delta printer.

Picture credit: Peter Langenhahn

Various functions and features integrated into a printed facade made from one material. Moritz Mungenast devised completely new, so-called functional geometries to fulfill functions like protection against sunlight or insulation.



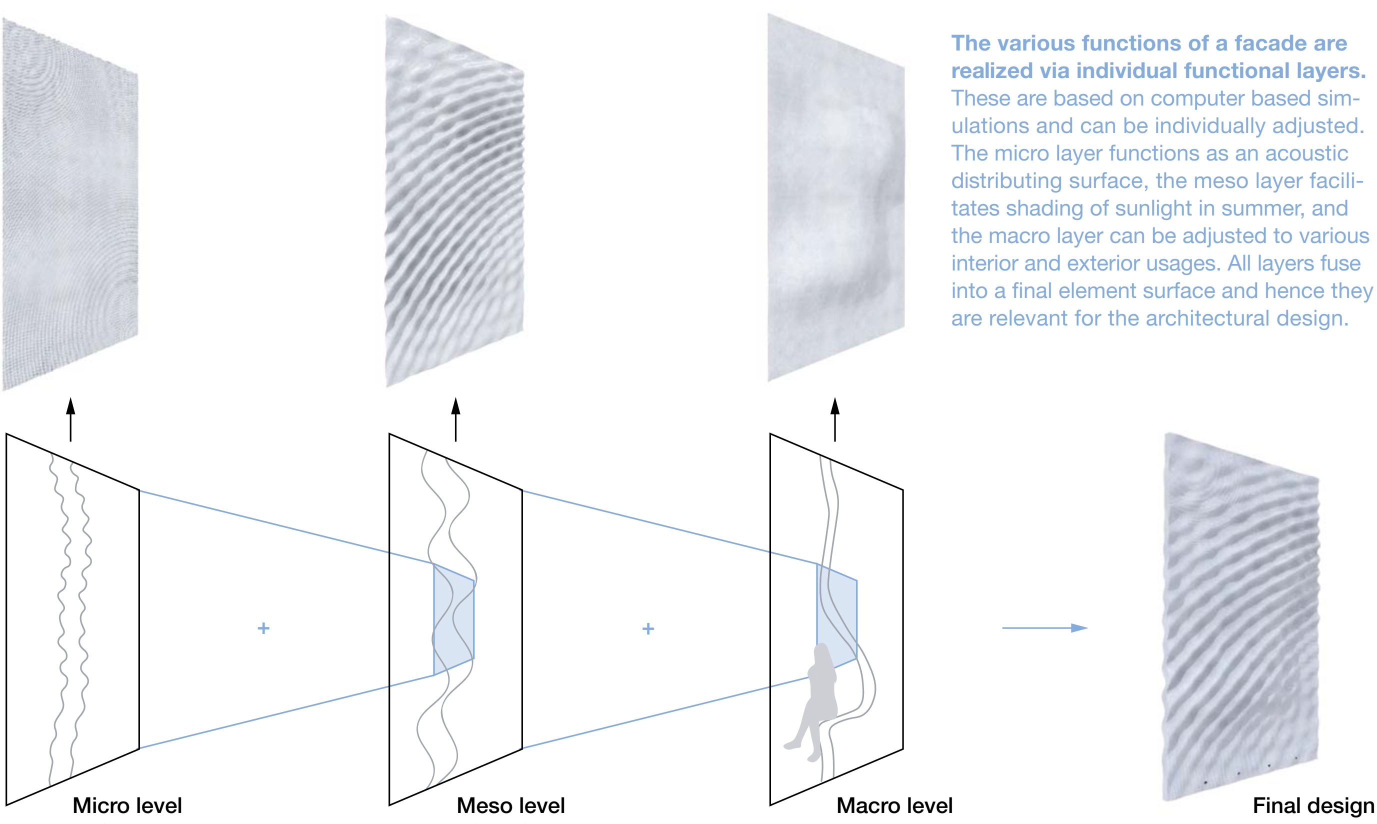
How did you settle on specific geometries?
There are various selection criteria: Can a geometry be printed? Does a suitable material exist? It's an iterative process: Several versions were printed, tested, and fine-tuned. With this kind of architecture, it's a case of research by design. The only way to make progress is to try things out. You get valid results when you make everything full-scale. Finally, the course of the sun is simulated with regard to the orientation of the facade. This has a decisive impact on the geometries, in terms of the shadow it casts, for instance.

What implications does this have for architecture?
Up until now, we've been in working architecture with more or less rigid systems, which we use for a range of construction tasks and sites. This means that you often have to make do with solutions that are a bit of a compromise. You use systems and modules that fit more or less OK wherever you are. Computational design allows us to devise tailored, sophisticated solutions for specific requirements and a specific location and to implement them effectively using additive manufacturing. ▷

"There's a lot of potential in developing new materials and a closed-loop material cycle for a transparent or translucent building envelope."

Moritz Mungenast

The various functions of a facade are realized via individual functional layers. These are based on computer based simulations and can be individually adjusted. The micro layer functions as an acoustic distributing surface, the meso layer facilitates shading of sunlight in summer, and the macro layer can be adjusted to various interior and exterior usages. All layers fuse into a final element surface and hence they are relevant for the architectural design.



Graphics: ediundsepp (source: M. Mungenast); Picture credit: Peter Langenhahn

What will you be moving on to next?

My overriding motivation is to make a contribution to the global construction tasks of the future. Although there are already solutions made from sustainable materials like wood for building designs, we're only just beginning when it comes to translucent facades. There's a lot of potential in developing new materials and a closed-loop material cycle for a transparent or translucent building envelope. To take the idea further, we set up the company 3F Studio. We just finished an application study for a 3D-printed, functionally integrated 250-square-meter facade to be produced on an industrial scale.

What material are you using?

The aim is to move away from conventional plastics. We definitely want to be working with biobased, sustainable raw materials in the future. PET, an oil-based plastic, was the starting point. We're currently using recycled plastic, made from old water bottles, for instance. In the future, we'd like to integrate algae or even chitin into our 3D printing and into the construction industry. Both these materials are translucent and lighter than glass. We're looking for suitable ways of producing transparent bioplastics. We'll be developing this further together with our partners for materials. ■

Thomas Edelmann

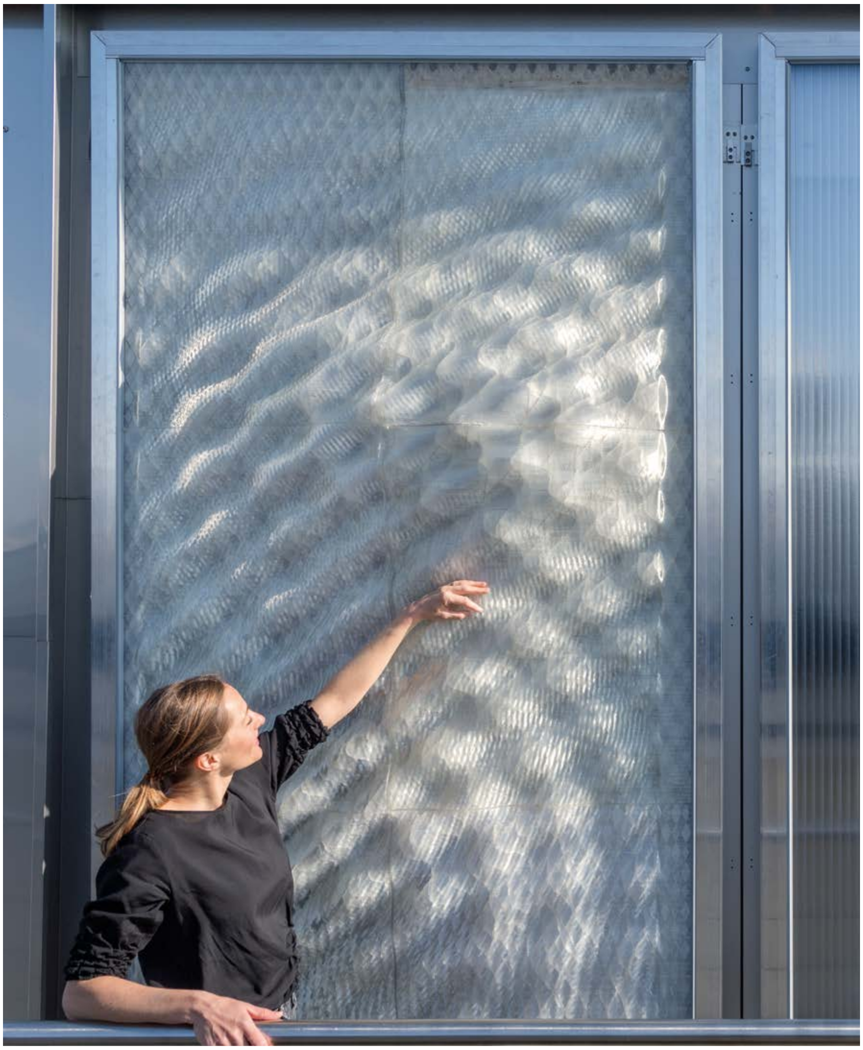
First-ever prototype of a 3D-printed, multifunctional, translucent facade. Test installation at the solar station of TUM in order to perform experiments for comparative tests and investigation of long-term behavior under various weather conditions.

1

production step required for a 3D-printed facade

>8

production steps required for a bespoke unitized facade



Picture credit: Andreas Heddergott; M. Mungenast

1

material needed for a 3D-printed facade

>6

individual materials needed for a bespoke unitized facade

Application study for a 3D-printed, functionally integrated facade to be produced on an industrial scale

At 750 square meters large, this first-ever 3D printed facade was designed for a temporary entrance at the Deutsches Museum, which is currently undergoing complete renovation. The design was produced by the TUM spin-off 3F Studio based on research conducted by Moritz Mungenast. It is a multifunctional, translucent facade made from recyclable material. The cellular structure of the facade elements produced from the 3D-printed cells ensures stability, while their air-filled cavities provide optimum insulation. Waves cast welcome shadows in summer. 3F Studio was founded by Moritz Mungenast, Oliver Tessin, and Luc Morroni and specializes in 3D-printed architecture and design.

15 kg

weight of 1 m^2 3D-printed facade

45 kg

weight of 1 m^2 bespoke unitized facade