What is 3D Printing?

While in the TV series, the replicator was envisioned to work by rearranging atoms to molecules first, and then forming the objects with those molecules, 3D printing technology is rather different. In short, it is the process of aggregating material, layer-by-layer. In fact, this concept of constructing objects from 3D model data is not new, it has been around for three decades. Although today’s state-of-the-art 3D printers look like toys compared to the fictional atom-scale assemblers, their capabilities are nevertheless impressive and are already quite useful to some industries. One of the most advanced applications is 3D printing with metal [2] This process has been defined by the final frontier in additive manufacturing. It can be implemented either by Selective Laser Sintering, where a laser beam fuses a powdered metal, or by depositing a powder metal matrix that contains a binder, which is melted at each layer until the final object gets baked in an oven. These technologies not only allow for the fabrication of complex mechanical parts at one go without the need for expensive molds or assembly, but they also allow for employment of geometries which is impossible using conventional machining or casting methods. As these techniques are still prohibitively expensive, they are more viable for niche markets rather than for custom mass production.

An alternative to direct metal printing is the 3D printing of sand casting molds, which still dramatically speeds up the production of complex metal specimens. [3] Sand printing allows large scale, very complex and accurate molds to be fabricated at comparatively low prices and has thus become very popular in the automotive industry.

The Cult of 3D Printing

What made 3D printing really popular is the fabrication of parts from plastic. While the employed materials do not yet meet the requirements set by final products, the technology nevertheless allows for the fast production of very revealing functional prototypes and 3D printing of plastic prototypes is becoming integrated in the workflows of industrial designers and mechanical engineers.

The popularity of this technology among designers has also been propelled by the emergence of specialised businesses, providing fast and reliable on-demand 3D printing over the internet, thus dramatically increasing its cost effectiveness [4].

The sociopolitical dimension of 3D printing, which promises to empower the individual to make almost everything, irrespective of economies of scale, is best represented by the ‘Fab Lab’ phenomena. [5] Fab Labs are small scale, low-cost digital fabrication workshops run by local communities at the grassroots level.

Since having been introduced by MIT’s Media Lab at the beginning of the last decade, Fab Labs and other maker-spaces are being developed worldwide, blurring still at the margins of fundamental research, the goal of these efforts is to print custom, fully functional human organs [9]. Yet another medical application, though so far is just an idea, aims to manage to print their medicine by using special chemical inks. [10] The instructions needed for the ‘on-the-fly

The Brave New World of 3D Printing

While the advances of 3D printing technologies propel our longing for where economies of scale do not matter anymore and everybody is turned into a potential designer of physical things, they also raise some challenging questions that reach far beyond issues of intellectual property or privacy and can get very physical indeed.

Despite being in favour of stricter gun control, what President Obama omitted in his speech is the fact that ‘Defense Distributed’, a company operating from Texas with the ultimate mission of giving everyone access to design files for 3D printing various gun components (Figure 3), has already managed to build working gun parts. Over 100,000 people all over the world have downloaded gun component blueprints from their website. [8] Motivated by the critical shortage of organ donations, researchers have started to investigate the feasibility of printing biological tissues. Although still at the margins of fundamental research, the goal of these efforts is to print custom, fully functional human organs. [9] Yet another medical application, though so far is just an idea, aims to manage to print their medicine by using special chemical inks. [10] The instructions needed for the ‘on-the-fly
molecular assembly’ could be downloaded from the Internet or delivered on a daily basis according to the course of the disease.

The possibility to print complex spatial fabrics with flexible materials has recently awakened the interest of fashion designers for 3D printing.[11] Spearheaded by haute couture, the textile industry has grasped the revolutionary potential this technology embodies and has started to creatively experiment with it (Figure 4).

While the conventional fabrication of textiles requires establishing a rigorous network of structurally interlaced threads, this constraint suddenly falls away with 3D printing. This allows for structures that would not be feasible with traditional techniques like weaving, knitting or crocheting. Alongside introducing radically new degrees of freedom, the possibility to produce very complex and differentiated fabrics fosters the emergence of novel aesthetic expressions.

But the most far-reaching and radical implication of the additive paradigm, at least from a designer’s point of view, is that it allows for fabrication of Functionally Graded Materials (FGMs). FGMs are characterized by a gradual variation of their physical properties and structure over their volume, meaning that gradual changes of the material properties are ‘designed’ and adapted to local conditions.[12] Being able to customize components for a specific function down to their local material characteristics, allows designers to make a more efficient use of the employed materials and thus being highly effective while being more sustainable.

3D Printing and Architecture

But how does 3D printing relate to architecture? The prospect of eventually being able to ‘print a whole house’ (Figures 5 and 6) is currently firing the imaginations of many stakeholders in the construction industry.

[13] But while this simplistic vision often completely overlooks the role of material properties, its feasibility is reduced to a mere quantitative issue. With the current technology it would simply take too long and thus be too expensive to print architecture.

Building something has always been an additive process (other than the manufacturing of goods, which until now has predominantly made use of subtractive or formative techniques), and has, as such reflected a sort of complex and differentiated 3D printing process. But what distinguishes architectural tectonics, which is the art of assembling building components into spatially defining structures, from 3D printing?

Architecture’s intrinsic ‘bigness’ turns material efficiency into an imperative, and it has fostered the development of ingenious construction techniques, making optimum use of the material properties. As a result of thousands of years of techno-cultural evolution, architecture has accumulated a wide range of processes, materials and components, each one possessing its specific logic, implicit intelligence and field of application.

The richness of this repertoire contrasts with the simplicity of current 3D printing processes, which are limited to the two dimensional layering of material at a fixed resolution. Speed can be increased, material properties tuned, and the worry about an impoverishment of the architectural discipline dismissed as nostalgic, but the generic character of 3D printing represents a severe limitation to its application at the building scale. It leaves no space for an architect to design or even modify the physical aspects of the process. The standardisation of the material deposition logic and printing resolution makes it difficult for the process to cope with the specific complexity of architecture. 3D printing implicitly promises a future in which the architect will be liberated from the constraints of material properties as well as from the burden of construction. Being able to fabricate virtually anything at the push of a button may feel appealing to some people. However, such an absence of friction and material resistance degrades the design process to a purely formal problem.

Notes

[8] Defense Distributed: www.youtube.com/watch?v=IcosGxYxA
[9] Printing Organs: www.youtube.com/watch?v=9RXm3IGnNXY

Further Reading

As many different relevant texts shape the ongoing discussion on architecture and digital fabrication it’s difficult to make a shortlist. As an expression of our personal position I would like to point to our book Digital Materiality in Architecture (Kohler, Müller, 2008.) Furthermore I would recommend the book by Medialab Professor Neil Gershenfeld Fab (Basic Books, 2005). This short but seminal book, published almost a decade ago, has provided the Fab-Lab movement with a theoretical, philosophical or even ideological background. It’s interesting to observe that also Gershenfeld, in recent talks, has shown to be irritated by the hype of 3D printing, claiming that digital fabrica-tion is much more than that.

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An Alternative to 3D Printing

At the Chair of Architecture and Digital Fabrication ETH Zurich, we have identified ‘Robotic Fabrication’ not just as an alternative but more importantly, an appropriate architectural equivalent to 3D printing.[14] In robotic fabrication (Figure 7), complex custom processes of material deposition, manipulation and assembly are carried out by industrial robots. While the industrial robot is truly generic as a mass-produced machine, the fabrication process is project specific. The physical manipulation on the material becomes a constitutive part of the design process, where it demands as much attention, care and creativity as the design of the robots’ actions. This genre of robotic fabrication processes will foster the evolution of a rich variety of new material systems as much as it updates traditional ones. These processes will be heterogeneous, address multiple resolutions simultaneously, and be able to adapt their constructive logic to the encountered geometry. Although layering is, as for bricklaying, appropriate to many traditional construction processes, robotic fabrication will go beyond this principle and become truly three-dimensional. And most importantly these design-specific processes will follow the desires and sensibility of the architect instead of being determined by a piece of standardised machinery.

While the replicator technology introduced in Star Trek more than 40 years ago is strong at reproducing already existing objects, it is not appropriate for the development of new ones. Expanding the conceptual domain of 3D printing to include bespoke robotic fabrication processes is the key to an architectural understanding of such systems and the conceptual precondition for the development of truly contemporary architecture.

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Materialize: www.materialise.com/press/
launch-of-the-first-fully-functional-flexible-material-in-3d-printing
Functionally_graded_material
[14] DFAB: www.dfab.arch.ethz.ch
www.futurecities.ethz.ch/research-modules/dfab

Figure 7: Robotic assembly framework by DFAB, ETH Zurich