DIGITAL FABRICATION:
FROM DIGITAL TO MATERIAL

Branko Kolarevic

Historically, architects drew what they could build, and built what they could draw, as William Mitchell observed. The straight lines and circular arcs drawn on paper using straightedge and compass have been translated into the materials made by the extrusion and rolling machinery. This reciprocity between the means of representation and production has not disappeared entirely in the digital age. In the realm of representation, the modeling software based on NURBS has infinitely expanded what could be “drawn,” while the digital fabrication technologies have substantially expanded what could be manufactured and built. As a result, the geometric complexity of buildings has increased dramatically over the past decade.

Furthermore, the digital age enabled a direct digital link between what can be represented and what can be built through “file-to-factory” processes of computer numerically controlled (CNC) fabrication. There is an unprecedented directness with which digital design information can be used in the construction of buildings. The consequence is that architects are becoming much more directly involved in the fabrication, as they can efficiently create the information that is translated directly into the control data that drives the digital fabrication equipment. A growing number of successfully completed projects, which vary considerably in size and budgets, demonstrate that digital fabrication can offer productive opportunities within schedule and budget frameworks that need not be extraordinary.

Various fabrication technologies exist today, which could be broadly grouped as CNC cutting, subtractive, additive, and formative. CNC cutting, or two-dimensional fabrication, is the oldest and the most commonly used fabrication technique, involving simple two-axis motion of the cutting head relative to the sheet material. Cutting technologies, based on superheated gases (plasma-arc), laser light and highly pressurized stream of water (water-jet), are broadly available and have been used extensively on a number of recently completed projects worldwide.

In CNC milling (subtractive fabrication), machines remove material volumetrically, by adding the ability to move the drill-bit along the third, Z axis. Large architectural firms, such as SOM’s office in Chicago, have used CNC milling machines in 1980s in the production of architectural models and studies of construction assemblies. The CNC milling has recently been applied in new ways in the building industry – to produce the formwork (molds) for the off-site and on-site casting of concrete elements with complex geometry. In one of the office buildings (Zollhof Towers) in Düsseldorf, Germany (2000), designed by Frank Gehry, the undulating forms of external wall panels, made of reinforced concrete, were produced using blocks of lightweight polystyrene (Styrofoam) that were shaped in CATIA and were CNC milled to produce 355 different curved molds that became the forms for the casting of the concrete. CNC milling can be also used to produce doubly curved molds for the shaping of glass panels with complex geometry, as

In a process converse of milling, additive fabrication involves incremental forming by adding material in a layer-by-layer fashion. It is often referred to as layered manufacturing, solid freeform fabrication, rapid prototyping, or desktop manufacturing. Because of the limited size of the objects that could be produced, costly equipment and lengthy production times, the additive fabrication processes have a rather limited application in building design and production. In design, they are used mainly for the fabrication of study models. In construction, they are used to produce components in series, such as steel elements in light truss structures, by creating patterns that are then used in investment casting.

In formative fabrication, mechanical forces, restricting forms, heat or steam are applied to a material so as to form it into the desired shape through reshaping or deformation, which can be axially or surface constrained. For example, plane curves can be fabricated by the CNC bending of rods, tubes or strips of elastic material, as was done in several pavilions designed by Bernhard Franken for BMW.

After the components are digitally fabricated, their assembly on site can be augmented with digital technologies. Digital three-dimensional models can be used to precisely determine the location of each component, move each component to its location and, finally, fix each component in its proper place. Components can be bar coded and the bar codes can be then swiped on site to reveal the location of each component by displaying them within the 3D digital model of the building. Electronic surveying and laser positioning equipment, driven by the 3D digital data, can be then used to precisely determine the position of each component.

The digital design information can be used directly in fabrication and construction to drive the computer-controlled machinery, making the time-consuming production of drawings unnecessary. This newfound ability to generate construction information directly from design information is what defines the most profound aspect of contemporary architecture. The close relationship that once existed between architecture and construction (what was once the very nature of architectural practice) could potentially reemerge as an unintended but fortunate outcome of the new digital processes of production.

The digital generation of information to manufacture and construct buildings can render the present inefficient hierarchies of intermediation unnecessary. By using digital building information models, the processes of describing and constructing a design can be now more direct and more complex because the information can be extracted, exchanged and utilized with far greater facility and speed; in short, with the use of digital technologies, the design information is the construction information.

It is this digitally-based convergence of representation and production processes that represents the most important opportunity for a profound transformation of architecture
as a profession and, by extension, of the entire building industry. By integrating design, analysis, manufacture, and the assembly of buildings around digital technologies, architects, engineers and builders have an opportunity to fundamentally redefine the relationships between conception and production. The currently separate professional realms of architecture, engineering, and construction can be integrated into a relatively seamless digital collaborative enterprise – a digital praxis.