Digital Fabrication: From Digital To Material
Branko Kolarevic

In the past, architects drew what they could build, and built what they could draw, as observed by Bill Mitchell. This reciprocity between the means of representation and production has not disappeared entirely in the digital age. Knowing the production capabilities and availability of particular digitally-driven fabrication equipment enables architects to design specifically for the capabilities of those machines. The consequence is that architects are becoming much more directly involved in the fabrication processes, as they create the information that is translated by fabricators directly into the control data that drives the digital fabrication equipment.

Some architects were quick to exploit the design and construction opportunities that were opened up by the newfound ability to digitally generate and supply the manufacturing information to fabricators and contractors, and, in turn, their ability to reciprocate by providing accurate material and cost estimates. In these newly discovered mutually-beneficial processes of direct information exchange, the digital design information became the construction information, and vice versa, without the intermediate time-consuming and error-prone steps of drawing production. These digital processes, pioneered by Frank Gehry’s office, represent a radical departure from the normative practices – they eliminate, rather than automate, the production of various construction documents as paper drawings. The digital data are passed on directly, i.e. in paperless fashion, to fabricators for cost estimation and fabrication.

The ability to digitally generate and analyze the design information, and then use it to directly manufacture and construct buildings, fundamentally redefines the relationships between conception and production – it provides for an informational continuum from design to construction. New synergies in architecture, engineering and construction start to emerge because of the use of digital technologies across the boundaries of various professions. As communication among various parties increasingly involves the direct digital exchange of information, the legacy of the twentieth century in the form of drawing sets, shop drawings and specifications, will be inevitably relegated to the dustbin of history. The need to externalize representations of design, i.e. produce drawings, will lessen as a direct consequence of the new digital possibilities for producing and processing information.

In this scenario, the digital model becomes the single source of design and production information (the “holy grail” of the computer-aided design research community) that is generated, controlled and managed by the designer. It encodes all the information needed to manufacture and construct the building. Layers of information are added, abstracted and extracted as needed throughout the design and construction, as architects, engineers, contractors and fabricators work in a collaborative fashion using a single digital model from the earliest stages of design.

For Gehry’s office, a digital model created in CATIA (Computer Aided Three-dimensional Interactive Application) – the design and manufacturing software used mainly in the aerospace industry – is the single source of design and construction information. In a remarkable departure from the current norms of practice, the three-dimensional digital model is actually a key part of the contract documents, from which all dimensional information is to be extracted during the fabrication and construction of the building. In other words, the digital model takes precedence over any other construction document, legally and in practice, on the construction site. This is a radical, revolutionary change in building practice, for which Gehry’s office will probably be remembered in future history books (and not only for the sinuous, curving geometries of the Guggenheim Museum in Bilbao, Spain).

It is this newfound ability to generate construction information directly from design information, and not the complex curving forms, that defines the most profound aspect of much of the 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. 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, in which architects could play a central role as information master builders, the twenty-first century version of the architects’ medieval predecessors.

Branko Kolarevic (Ddes, Mdess-Harvard, Dipl.Ing.Arh.-Belgrade) teaches design and digital media courses. Prior to joining Penn in 1999, he taught at several universities in North America and Asia. He has lectured worldwide on digital media in design, and has authored and edited several books. He is a former president of ACADIA.

Connecting Digital Fabrication
Marta Male-Alemany

We live a period where the digital revolution seems to reach a first stage of maturity. After new technologies introduced a higher degree of efficiency and versatility in traditional design processes, recent research focuses on the experimentation and application of specific potentialities of the digital for both the generation and material production of architecture.

The end of the century was the beginning of the integration of computer aided manufacturing (CAM) processes into architecture. Widely used in the industry, computer driven fabrication systems promised to develop building technologies in new directions. Today, this tendency is a widely spread reality, both in practice and architectural education.

Digital fabrication in architectural practice
As CAD-CAM technology becomes more affordable and available in the market, a number of contemporary large offices—which include Gehry Partners, Foster Associates, Grimshaw—have used digital production technologies to resolve construction issues related with the execution of complex geometries and optimise the production of their building components.

At another level, an increasing array of smaller practices have instead incorporated CAD-CAM processes as part of their design agenda; architects like Bernhard Franken, DeCo, Garofalo Architects, William Massie, SHoP, or Kolatan & Mcdonald are exploring the conceptual and material opportunities that emerge from a simultaneous employment of digital design and manufacturing techniques. Furthermore, while design information now drives numerically controlled machines, research also goes on exploring an inverse interference: how fabrication data can affect creative processes at the level of design foundation.

Digital fabrication in architectural education
The same interest has grown in education. Envisioning emergent changes in the profession, many schools of architecture have started to integrate digital production equipment as part of their facilities.

The academic exploration on CAD-CAM processes stimulates the convergence of otherwise separated subjects (such as design and construction), setting up new conditions for teaching architecture in studio environments. While the computer has proven to be a suitable media for the development and communication of architectural projects, numerically driven machines stimulate testing design ideas in the physical world. The move from simulation/representation to realization/execution is strongly encouraged by the possibility to fabricate complex, non-standard forms with extreme precision and control. With the possibility to build parts at 1:1 scale, the design studio reaches out to the execution of actual buildings.

In fact, and no matter how expensive the investment, the implementation of CNC equipment is an important step for academic institutions to build and consolidate their vocation: the opportunity to play a central role in driving innovation.

Concluding notes
Today digital fabrication is a vibrating context for theoretical and applied research in architecture, which touches on almost all the dimensions of the discipline.

An overview of this context highlights changes in-progress and opens the perspective of others to come. When architecture becomes closer to the construction industry, these digital design and manufacturing technologies are indeed reconfiguring the role of the architect in the midst of building processes. Similarly, the convergence of several fields of expertise—as they come together in a continuous design-to-manufacturing processes—stimulate a new dimension of interdisciplinarity and collaboration.

No longer dependent on standardization paradigms, there are real conditions and possibilities for architecture to take advantage of mass-customization production processes with visible effects on the building environment. In this context— and given its potential for research & development—academia can strengthen the link with the reality of practice. By focusing on a theme that has important consequences in the building environment, architecture schools can create new conditions for education in design studio environments, and play an important role in driving innovation in the production processes architecture.

Marta Male-Alemany (B.A. ETSV-UPC, Barcelona, MS.AAD Columbia University) has taught at UCLA and is currently with the design faculty at SCI-ARC and ESARQ-UIC. Parallel to her academic dedication, she works as an independent architect and digital production consultant. In her practice, she investigates both conceptual and material opportunities that emerge from the use of advanced CAD-CAM applications. Recent works on digital production include a bench structure for the Barcelona Forum 2004 and an installation at SCI-Arc Gallery. She has been writing and lecturing on the subject of digital fabrication.