

Chapter 2

Innovative Construction Systems: New Design Aesthetics Through Competitive Realization Processes

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ABSTRACT

With the emergence of a new materialism in architecture and as a result of the ongoing advancements in digital technologies, computer numerically controlled (CNC) fabrication and 3D-printing are rapidly gaining popularity within the building construction industry. Robots, CNC machines, and algorithmic programming allow us to create new construction systems and innovative designs that otherwise might not be possible. This chapter analyzes adaptive and flexible systems that facilitate the design and the production processes of mass-customized building components through digital fabrication and assembly. The aspiration is to achieve morphological complexity and performance in material constituents: an engineering computational design process that envisions a sustainable built environment, with higher-level functionality and higher-level integration between material system and environment.

INTRODUCTION

This chapter describes the original contribution developed by the author with the help of his team (E.Gamba, M.Sangiorgio, D.Cucchi, M.Dragoljevic) regarding the digital design and production processes of three construction systems, specifically:

1. Robotic manufacturing system for mass-customized insulated wall panels;
2. Responsive louvers system for adaptive façades;
3. Topology optimization system for spatial structures.

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Several models and prototypes have been built in order to validate the assumptions. The experiments draw attention to how digital technologies generate the efficiencies for mass customization of real world building systems.

This research demonstrates how digital fabrication can establish a loop between physical performance aspects and the development of a custom design system.

By integrating digital fabrication technologies into the design and production process, novel forms of architectural materialization can be explored.

The chapter begins with a description of the state of the art regarding contemporary design, manufacturing and assembly strategies; it is subsequently organized in three sectors, describing each system.

DESIGNING DESIGN, MANUFACTURING AND ASSEMBLY

Pattern and Transformation

Modernist architecture sought to establish consistency between parts and wholes through modular logics made possible by the processes of industrialization; these methods relied on regulating systems and planning grids to organize space.

Nowadays advances in digital technologies and algorithmic programming allow for a shift towards an automated deformation of the grid in order to morphologically adapt to the environment. The modernist model of the simple repetition of unchanging units has been replaced with a model of variable units repeated along variable trajectories (Reiser, J. 2006). The systems proposed in this chapter will show how it is possible to organize flexible part-to-whole relationships that can grow and differentiate to produce patterns of complex material-organizations.

The potential of digital design and fabrication processes can best be exploited where a large number of discrete elements are combined as part of a self-similar structure. The deployment in quantity and the difference in degree between the elements allow to perceive a sense of transformation of the whole. Essentially the whole becomes greater than the sum of its parts. The possibility of generating formal signs of “transformation” in the design of architecture is related to a mathematical model’s ability to describe variation. In this respect, the notion of pattern has re-emerged within architectural design, specifically as a critical tool for managing large quantities of information throughout the design process (Picon, A. 2010).

The theme of transformation finds its foundations in the studies of the Master Albrecht Dürer (1471 – 1528), his work on human proportions and “deformation grids” (Dürer, A. 1528) proposes a relativist notion of beauty based on variety and could be considered a reference point for a contemporary architectural discourse. The biologist and mathematician D’Arcy Thompson (1860 – 1948) revisits Dürer’s approach in order to illustrate and formalize shape differences between geometrical objects. Thompson described how the differences between the forms of related species can be represented geometrically through the transformation of the rectangular coordinate system into a curvilinear system that stretches the geometries of the analyzed species.

The definition of form as “a diagram of force” appeared in Thompson’s book *On Growth and Form* (1917) and continues to instill the principle that the design of forms in the built environment should be driven by structural intuition in a dialogue among materials, performance, geometry and aesthetics.

Another inspiring contribution is the one embedded in the powerful paradigm of “Epigenetic Landscape”, illustrated in a diagram as attracting valleys resulting from a complex regulatory network (Wad-

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