CNC Milling as Foundation for Life

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INTRODUCTION

Architectural ornament has seen a resurgence with the application of digital design and fabrication technologies. At the same time, ornament has shifted from purely symbolic function to high performance facades that conserve energy, or, in some cases, generate their own. Coupled with this high-performance metric is a renewed interest in expressive textures and articulated facades made largely possible by digital manufacturing.[1,2] The tools that support these innovative designs have also found success in replicating and restoring historic structures, thus broadening their impact and relevance to the profession. Moreover, from an ecological perspective, digitally-derived ornamentation may have the potential to address the emerging crises of species extinction and habitat loss, particularly near urban areas where the cumulative surface area of buildings and hardened landscapes exceeds that of natural settings by several orders of magnitude. These architectural, urban and landscape surfaces represent an opportunity to facilitate life itself within the built environment, and in many ways, could be the designer's greatest opportunity to include biodiversity as criteria for design of sustainable and resilient built environments.

CONTEXT FOR THE PROJECTS

Throughout history, ornament has been integral to architecture. In early human civilization, architectural ornament was applied to buildings of worship and places of civic importance. In many cases, these expressive details utilized iconography and geometrical patterns to inform a largely illiterate population. They referenced historical events and provided symbolism that connected the viewer to the significance of the building, place or events that surrounded the architecture they adorned.[3] Ornament from each region developed with the vernacular and eventually became appropriated stylistically as global trade, migration and colonization distributed these designs across the world. Serving as both evidence of diverse architectural styles and a catalogue for the contemporary designer of the late 19th Century, Owen Jones's *Grammar of Ornament* documented the regional variations on geometrical, flora and fauna ornamentation in architecture.[4] Examples include columns from ancient Egypt depicting papyrus and other flora of the Nile River, which served as a lifeline for food and transportation for the Egyptians. These architectural details are early forms of biomimicry and signify the interdependence of human communities and the natural landscape.

Figure 1. Ornament depicted human reverence for nature and incorporated symbolism of significance to a region. Owen Jones, *The Grammar of Ornament*. originally published 1856.

Styles continued to migrate and merge through the end of the 19th Century, culminating with the near ubiquitous adoption of terracotta into high-rise construction and the ornate detailing that followed. Discourse in architecture at the time signaled a split between those adopting Euro-centric references (i.e. Beaux-Arts style) and those aiming to reconnect architectural ornament to regional references (i.e. Prairie Style, Organic Architecture).[5]

Ornament was largely avoided during the early and mid- 20th Century, with the adoption of International Style, thus breaking with centuries of architectural tradition. Ornament became scorned by the profession, with commentary such as Adolf Loos's *Ornament and Crime* characterizing architectural ornament to

Figure 2. Terracotta detailing in the late 19th and early 20th Centuries ushered in a wave of architectural ornament in a variety of styles. Shown is a digitally fabricated replica of a cornice frieze detail from Louis Sullivan's Wainwright Building in St. Louis. Image credit: Author's design-build studio project.

be considered untrustworthy as that of tattoos on a criminal person.[6] Although, much of what caused distaste for architectural ornament early in the 20th Century stemmed from the economics of human labor required to achieve such exquisite designs and the parallel embrace of the efficiencies of factory assembly lines.

More recently, a resurgence of natural patterns in architecture, fueled by a shift toward conservation and awareness of natural systems, has capitalized on digital technologies to create bespoke, contemporary facade systems that incorporate biomimetic principles and performance.

ORNAMENT AS ECOLOGICAL SYSTEM

Buildings and the attendant landscapes have replaced natural systems with mostly uninhabitable surfaces. Finding opportunities for habitat within the built environment, also known as "win-win ecology," has become critical to reverse habitat loss and reintroduce ecological services and species diversity within urbanized landscapes.[7] With the exception of an occasional green roof or incidental nesting ledge, the surfaces of buildings, bridges, retaining walls and other built elements remain distinct from ecological systems.

Digital tools leave a signature, or "maker's mark," that, if harnessed, can enhance textures with functionality at multiple scales. Creating textures at the scale of tool and tool path can add to the aesthetic of surfaces, enhancing the shadows and adding sculptural relief. In some cases, the added texture may create conditions for biotic systems to adhere to, in which case the added surface area and rugosity of the surface texture could be calibrated to specific organisms.[8] The textures could

Figure 3. Terracotta as a facade cladding has seen a resurgence in the 21st Century. Shown above is a concept for a self-shading terracotta façade system supportive to local wildlife with nesting areas, produced using digital tooling and ram press technologies. Image credit: Author's design-build studio project.

modulate the thermal performance of the surface by affecting solar orientation, as well as create conditions for water retention, altered airflow and other environmental interactions. Undoubtedly an interdisciplinary endeavor, the designer must collaborate with the sciences to create meaningful design criteria to connect facades to ecological systems.

Projects to explore these concepts were undertaken within design-build studios and ongoing faculty research.[9] Digital design and manufacturing formed the basis to highly expressive building façade concepts developed in terracotta and a marine-friendly seawall application. The terracotta projects include a historic detail replica of the cornice frieze from Adler and Sullivan's Wainwright Building (1891), an oyster mushroom-inspired tile pattern that self-shades and creates nesting habitat, and a tile concept to facilitate moss and lichen growth on building surfaces [Figs 2-4]. Digital tooling played an important role in each project. For the cornice frieze, digital modeling and CNC milling created precision that surpassed the original terracotta on the building. The oyster mushroom project utilized tooling to create texture in a Ram Press mold. And the moss project utilized

Figure 4. Concept for a terracotta moss and lichen substrate generated by digitally-sampled images of earthen, stone and tree bark textures. Image credit: Author's design-build studio project

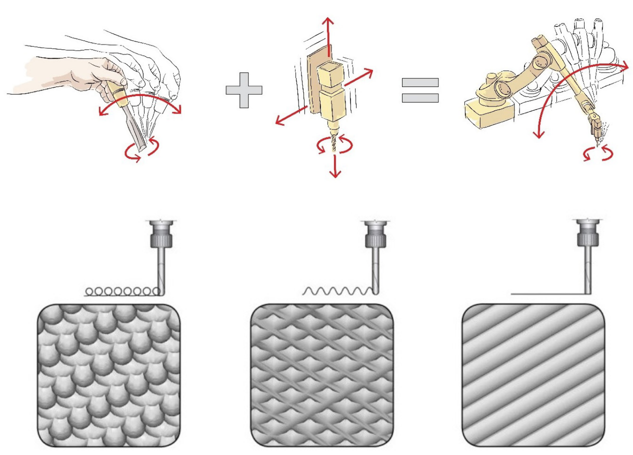

Figure 5. Digital tooling is analogous to the craftsperson's mark. By coupling digital tools with specific ecological systems, architectural surfaces could support diverse life. Image credit: Kelly Winn[10]

Figure 6. Prototype concrete relief panels cast from digitally milled molds. Oyster reefs were image sampled to create the panel form, with CNC milling creating the surface texture. Image credit: Author

Figure 7. Biomimetic seawall concept utilizing digital design and manufacturing to create habitat and texture to support marine life. Image credit: Author.

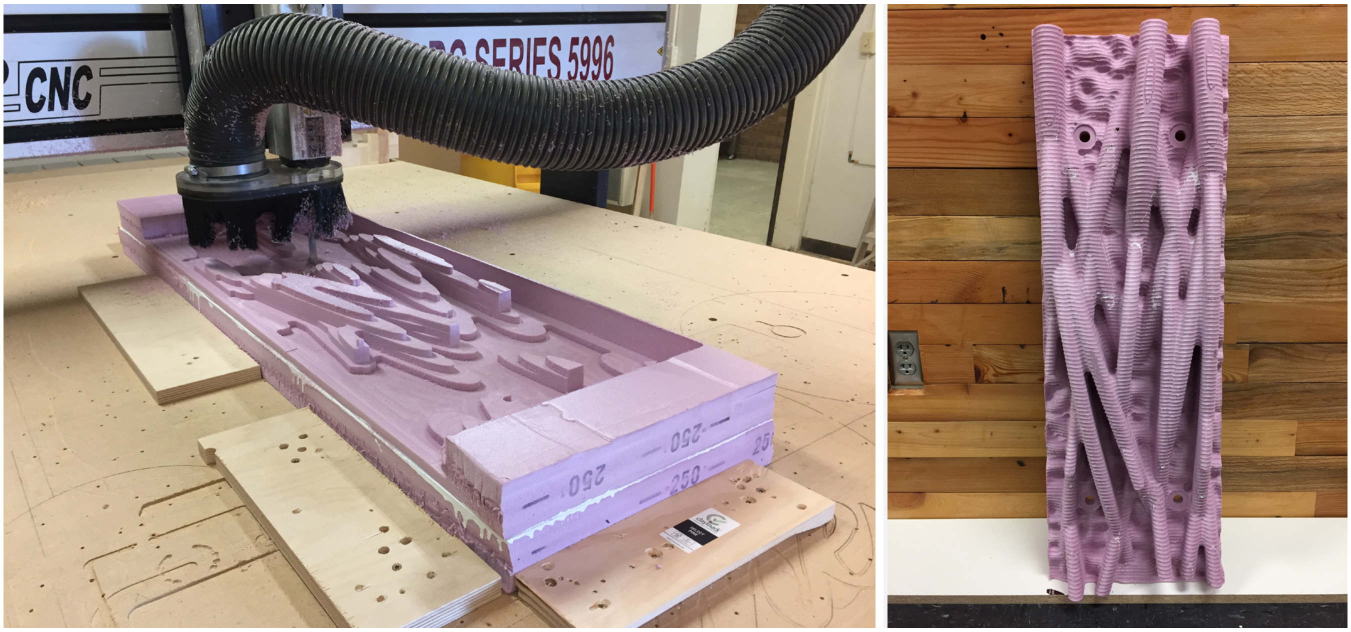

Figure 8. CNC milling foam master mold of the biomimetic seawall panel. Image credit: Author.

Figure 9. Detail view of texture on prototype panels installed in Southwest Florida. Marine-friendly concrete was used to accelerate recruitment of marine life. Image credit: Author.

Figure 10. Adjacent mangrove roots and panels at 18 months showed similar patterns of biological recruitment. Image credit: Author.

finely spaced tool paths to replicate the formal properties of various moss substrates.

The final application explored an alternative seawall that incorporated digital modeling and CNC surface milling to create textures that promote biological recruitment in a marine environment [Figs 6-10]. This application of digital tooling blended mangrove root patterns with seawall panels to create root-like forms projecting outward from the face of the seawall. The patterns were parametrically modeled from data on the red mangrove (Rhizophora mangle) and depicted the density and habitat characteristics of root systems found in mangrove forests. The aim of the design was to create a structural substrate for 'foundation species,' such as oysters, which form a community base, and increase the diversity, resiliency, food web complexity, and productivity of ecosystems.[11] To create the texture, CNC tool paths were broadly spaced to mimic the rugosity of roots with oysters and barnacles already established.

ENDNOTES

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