Digitally Mediated Regional Building Cultures

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Abstract
Designs are complex energy and material systems and products of diverse cultural, economic, and environmental conditions that engage with their extended context. This approach relates architecture to the discourse on complexity. The design research described in this paper introduces an extended definition of ecology that expands the scope of design discourse beyond the environmental performance of materials and types of construction to broader cultural considerations. Parallel to enabling rich formal explorations, digital modeling and fabrication tools provide a basis for engaging with complex ecologies within which design and building exist. Innovative design applications of digital media emphasize interdependencies between new design methods and their particular context in material science, economy, and culture. In British Columbia, influences of fabrication and building technology are evident in the development of a regional cultural identity that is characterized by wood construction. While embracing digital technology as a key to future development and geographic identity, three collaborative digital wood fabrication projects illustrate distinctions between concepts of complexity and responsiveness and their application in design and construction.

1. Responsiveness and interaction

Architectural designs must be understood as complex energy and material systems and products of diverse cultural, economic, and environmental conditions that engage with their extended context. This approach equally applies to design at the scale of objects, buildings, and cities and relates architecture to the discourse on complexity. The design research described in this paper introduces an extended definition of ecology that expands the scope of design beyond the environmental performance of materials and types of construction to broader cultural considerations. In addition to enabling rich formal explorations, digital modeling and fabrication tools provide a basis for engaging with complex ecologies within which design and building exist. Digital modeling with parametric features, in particular, offers responsive design methods that facilitate engagement with a range of dynamic parameters. By establishing relationships between elements of a design that are analogous to mathematical equations, element parameters can be manipulated while constraints and dependencies between elements are maintained. The resulting dynamic models are able to respond to changes and offer a high degree of flexibility and coordination. These processes apply to everyday considerations of design, fabrication, and construction and to conceptual explorations of dynamic conditions.

The responsiveness of parametric modeling and related digital design techniques broaden possibilities for the integration of diverse references into the design process. By extending the range of aspects and parameters considered in the design process, digital design encourages innovative design responses to regionally specific conditions. As novel re-readings and exploitations of existing contexts, innovative designs that extend the range of aspects and parameters considered in the design process emphasize interdependencies between new design methods and their particular ecology. Using an expanded definition of ecological design grounded in its material, economic, and cultural context, material expressions become significant references for innovative design and production. Therefore, particular modes of production and craft play a central role in design grounded in ecology with interdisciplinary collaborations in design, building, and research reflecting discursive engagements a cultural environment in flux.

While modern science often relies on an anthropocentric understanding of the environment, ecological design is grounded in interrelationships with "a repertoire of operatives affected by time, patterns of connectivity, and changing populations of multiple components."[1] Accordingly, an extended definition of ecology expands the scope of design beyond the environmental performance of materials and types of construction to broader cultural considerations. In a common approach that focuses on the natural environment, ecological design incorporates "a complex set of interdependent interactions…, which must be regarded dynamically."[2] However, the expanded definition of ecology outlined here looks beyond environmental considerations to include cultural, social, and ecological factors. Tradition and craft are two reference points for ecological design that acknowledges the need to position digital explorations in architecture as part of a "hybrid discipline"[3] with collaborations of architects, engineers, material scientists, companies and practitioners. Innovative ecological design approaches embrace digital technology as a key to future development and geographic identity, as aspects of place now include interrelated natural and man-made conditions, including social, cultural, economic, and technological factors.

In this framework, spatial concepts are informed by the logic of fabrication and methods of assembly. A reciprocal relationship between technology, space, and locale suggests that the introduction of new technology generates new spatial concepts. While situating context-specific design at the intersection of local and global influences has been a common theme since the early 20th century, when industrialization and the increase of mass-produced building materials promoted a sense of regionalism as a reconciliation of local and global influences, modern applications of technology have often been treated as independent of space and place. With the development and incorporation of digital technology into the design process, however, design interventions can be integrated into their respective context.

2. Digital technology and regional formation

Design that engages in the conditions of a location requires attentiveness to the dynamic particularities rather than generalized concept of place. In British Columbia, where influences of fabrication and building technology are evident in the development of a regional cultural identity, modern architecture and industrial design resulted from the integration of international and local influences. While plywood furniture design combined a modernist sensitivity and fabrication methods with local influences, modern West Coast post-and-beam architecture synthesized cultural influences from Europe with local craft and geographic conditions of climate and topography. Today, as standardization and mass-production have given way to mass-customization processes, digital fabrication technology offers an opportunity for an architectural culture that simultaneously looks to global developments and to the particularities of the local context. Geography takes on a broader definition that encompasses social, economic, cultural, and technological factors of a given locality, and their global influences. In the Pacific Northwest, this particularly applies to wood construction.

In British Columbia, wood figures as a primary characteristic of place in several ways: the particular B.C. ecology with forestry as a principal economic factor; the development and use of wood products and their industries and craftsmanship; and, available contemporary wood fabrication technologies. In the face of limited wood supply and growing pressure from foreign producers, the British Columbia lumber industry depends on technology to enhance the value of wood products to remain competitive. Global economic competitiveness requires the ability to export ideas, technological know-how, and sophisticated building techniques. Therefore, the focus on invention in building methods through technology in design is critical when considering global competition where finite resources, growing environmental awareness and a focus on the preservation of natural resources are central aspects of a regional building culture that is environmentally sensitive and economically viable in the long term.

Three recent wood fabrication projects illustrate aspects of the integration of architecture into its extended context. Situated in British Columbia, the projects explore the potential of digital modeling and fabrication technologies to contribute to regionally specific designs. While each of the design-build projects engage in a range of conditions concerning the relationship of ecological design, digital media, and fabrication technologies, the projects are categorized to foreground particular aspects of the mediation of regional building through digital media, design tools, and logics of fabrication. Digital design and fabrication tools are used to generate "forms that can be built effectively, ... (to) achieve a balance between aesthetic intrigue, innovation and efficiency in new structural forms"[4] as a direct reflection the ecological condition that constitute their extended context. Borne out of a comprehensive procedure that identifies and explores a range of social, economic, and environmental factors that figure into the generation of architecture, the regionally specific structures are seen as expressions of regional formation rather than as built forms autonomous of their production processes.

2.2. Naramata Roof Structure: digital fabrication – concepts and application

Figure 1. Completed roof structure

Digital fabrication tools such as CNC beam processors provide a direct link between computer-aided modeling and physical form. The digital output devices allow for the direct translation of conceptual models into built form and promote evolution of practical aspects of traditional wood building methods. The ensuing designs allow the development of culturally responsive designs and buildings that explore the dynamic relationship of technology and culture, economy and landscape. Their resulting spatial organizations and formal expressions demonstrate an evolving architecture rooted in complex ecologies.

The Naramata Roof Project explores CNC wood fabrication technologies for the design, fabrication, and assembly of a small roof structure for farm use in Naramata, British Columbia. The roof is intended as a protected meeting and workspace for the farm community. The project includes research on wood joinery and wood structures, as well as the design of the roof, preparation of the construction site, the fabrication of roof components, and the assembly of the wood structure at the site. The realization of the project included the use of a variety of media, fabrication, and construction methods. The Naramata Roof Structure highlights the potential of digital wood fabrication technologies for the design and fabrication of a context specific project. The research also illustrates effects of the translation from digital design media to building as the particular conditions for the use of digital design media, wood fabrication software, wood fabrication technology, and for the assembly of the structure at the site, all contribute to the built project. A particular focus of the project was the translation of the design concept developed using digital modeling and wood fabrication software into the built structure. Material tolerances, assembly sequences, and the accuracy of the digital fabrication process as well as the limitations of manual construction methods under site conditions constituted limiting factors for the project.

Designed as a structural truss , the Naramata Roof Project is fusing the principles of a truss and a space frame. Deploying a mirrored array of three dimensional components to form the overall roof, the structure is designed to form and operate as a three dimensional configuration rather than an array of planar structures linked together with a sheathing or cladding.

The project illustrates that mass-customization processes using digital design media and wood fabrication technology allow for the material- and time-efficient translation of spatially complex designs. Variations of joints and building configurations that respond to site, program requirements, and available materials can be generated without compromising the efficiency of the fabrication process. Similarly, the research project reveals distinctions between conceptual and spatial potential of digital design and fabrication technologies' flexibility and responsiveness and the actual application in design, fabrication, assembly, and construction that reflect the limitations of each phase of the design and building process.

Figure 2. Digital modeling, CNC fabrication, and assembly

Initially, design concepts were developed using Rhinoceros 3-D modeling software and physical model studies. To prepare data for wood fabrication, digital design models were then imported into Cadwork wood fabrication software. Subsequently, the fabrication data was used to fabricate components of the wood roof structure on a Hundegger K2 CNC beam processor. In a final step, the pre-fabricated components of the wood structure were assembled. Additional OSB sheathing, aluminum flashing, and roofing were then prepared and installed at the site.

The particular context of the Naramata Roof Project includes the conditions at the site, program requirements, available design and fabrication methods, building materials, and methods of assembly. As a group design and building project, exchange and interaction between members of the research team are also central contributing factors to the quality of the design and building. Similarly, the integration of the project into its particular context of design and fabrication illustrates both potentials and limitations for the design and building process. The translation of the digital design model into Cadwork fabrication software takes the available tool setup of the Hundegger K2 4-axis router used for the fabrication of roof components into consideration. The roof configuration and joint geometry are adjusted to acknowledge the particular tool set of the available 4-axis router. In addition to avoiding compound angles, processable lumber sizes are considered in the design revisions in Cadwork with the choice of lumber sizes and quality directly affecting the joinery design. The positioning of connecting bolts is coordinated with available drill bits, router sizes, and tool path limitations. In addition, repeated joints and wood configurations are copied during the design process in Cadwork to promote efficiency in the fabrication process by minimizing the generated fabrication data and related fabrication times.

2.3. Loon Lake Cabin: environment and economy

Figure 3. Project diagram and main elevation

The Loon Lake Cabin built with Solid-Wood-Wall panels explores the potential of mass-customized Solid-Wood-Wall technology for a regionally specific design sensitive to its ecology. The project focuses on the spatial, economic, and environmental implications of the panel construction method. Material characteristics and spatial configurations particular to Solid-Wood-Wall construction are investigated in the context of the British Columbia building culture and the particular cultural, economic, and environmental conditions of the region and site. The compact design of the cabin references existing campground architecture and is intended to maintain the character of the campgrounds while introducing contemporary wood building methods.

Figure 4. Solid-Wood-Wall panels, concept elevation + plan configuration

The project for a cabin built with Solid-Wood-Wall panels is a collaboration between the University of British Columbia Research Forest, the Hundegger Maschinenbau GMBH based in Germany, the UBC School of Architecture and Landscape Architecture, the UBC Centre for Advanced Wood Processing, and participating engineers. The project includes research on the spatial and environmental implications of Solid-Wood-Wall construction methods. Digital wood fabrication, material characteristics, environmental performance and spatial configurations particular to Solid-Wood-Wall construction are explored to identify the relevance of Solid-Wood-Wall construction in the context of the British Columbia building culture and the particular economic and environmental conditions of the region. As a building method that uses large amounts of wood, Solid-Wood-Wall construction responds both to current environmental and economic necessity to utilize large quantities of beetle-infested wood in British Columbia within a short time period. Given that some areas of British Columbia will see up to 80 percent of its mature pine trees killed by the beetle infestation in the near future, Solid-Wood-Wall construction offers an opportunity to utilize the affected wood for building components with high environmental performance and to avoid economic and environmental damage from dying forests in the region. With its inherent sustainable and structural qualities the new construction product and method can address current environmental and economic challenges.

2.4. Loon Lake Outdoor Theater Roof: context and expression

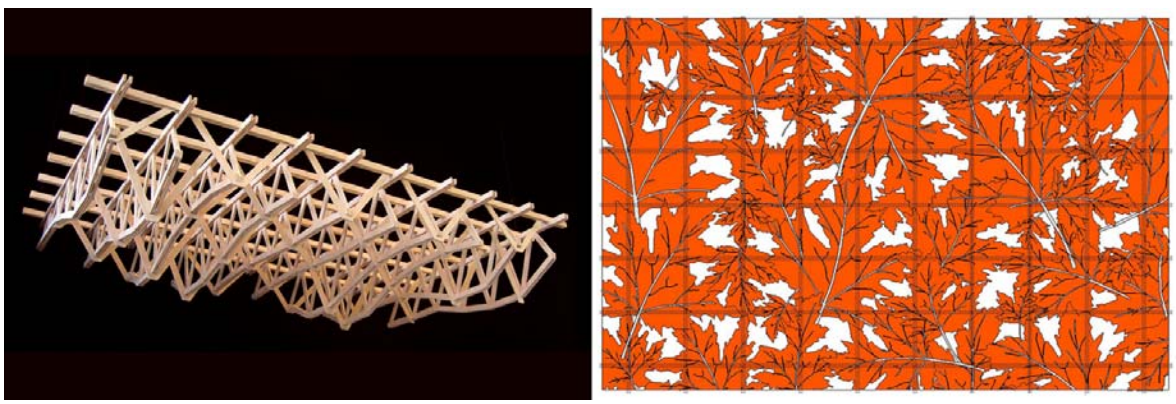

Figure 5. Initial space-truss configuration and perforated horizontal plywood diaphragm

The Loon Lake Outdoor Theater Roof takes large scale CNC fabrication technologies as a starting point for innovative wood construction methods that build on the B.C. wood building tradition and the existing forestry industry to promote sustainable wood building designs through material efficiency and efficiency of assembly. Given this focus, the design research is intended to contribute to the transformation of the B.C. wood industry from a resource-based to a technologically sophisticated and knowledge-based economy. The design is both rooted in its local circumstances and reflective of larger processes addressing technology's potential to generate designs consistent with the conditions of their extended context. While the design aims to satisfy the specific needs related to program, climate, and locale, the design project considers a scale beyond the site and immediate context of its intervention, referencing complex processes that equally influence and are affected by the design.

The roof project illustrates digital fabrication technology's potential to generate designs consistent with the conditions of the place of their intervention. The design research project uses CNC timber framing software and CNC fabrication technology to build a material-efficient wood roof structure that meets the requirements of the local program and site conditions while exploring forms and expression particular to digital fabrication technologies. As a product of a multidisciplinary collaborative design process including architects, engineers, material scientists, digital fabricators and software developers, the roof reflects the diversity of aspects implicated by the use of digital wood fabrication technologies. Utilizing existing columns, the roof provides cover for small open-air stage. As a light and open structure, the roof preserves important visual relationships of the outdoor theater seating to the surrounding forest and lake beyond. A visually perforated roof plane promotes the integration of activities on the stage into the surroundings with sunlight and shadows from surrounding trees animating the roof structure and stage below.



Figure 6. Project site + revised roof configuration

Similar to the previously described projects, the theater roof project explores technical, spatial, and cultural aspects of CNC wood fabrication. References for the project are technological innovation and formal expression of contemporary wood structures. The roof project illustrates how spatial concepts are informed by the logic of fabrication and methods of assembly. With a focus on material efficiency and contemporary interpretations of wood-to-wood joinery, the roof design explores the materially and structurally efficient use of small wood members in a non-hierarchical space-truss configuration. The lightweight material-efficient roof is designed to minimize the number of necessary wood members and to simplify the wood-to-wood joints. Hung from existing columns, the space truss configuration with a perforated horizontal plywood diaphragm for rotational stability responds to the load conditions in the trusses with the underside of the structure shaped to reflect the moment forces in the structure. Equally, the roof design introduces a scale independent of the size and resolution of the wood structure. While the structural logic of the project responds to the forces in the roof and to the orientation of the stage towards the audience, the design references the complexity of the projects extended context by introducing a graphic pattern autonomous of the size and resolution of the wood structure.

3. Digitally mediated regional designs

As collaborative design-build projects that depend on the cooperation of structural engineers, wood scientists, software developers, and fabricators, the multidisciplinary projects illustrate the complex relationships and conditions particular to design grounded in its broader ecological context.

Forestry, wood building materials, and wood building methods are essential aspects of the cultural context of the Northwest. The collaborative projects are focused on promoting the integration of digital techniques into regional design and construction practice, and on illustrating how digital modeling and fabrication can contribute to the conception of new building methods and spaces. By exploring how digital fabrication leads to conceptual explorations and form-finding processes that influence existing design and construction practices, the research projects contribute to the necessary transformation of the regional wood industry in the Northwest from a resource-based economy to an economy based in knowledge and global competition.

This paper has illustrated that CNC fabrication technologies can produce new spatial and material expressions consistent with the notion of complex environments. Given the capacity to efficiently create ever-smaller building modules and spatially complex building components, CNC-fabricated wood building elements can be designed to meet the specific and changing requirements of individual building projects while promoting efficiency of material use and assembly. The CNC fabrication processes allow the efficient application of mass-customization technologies and the exploration of formal and spatial conditions corresponding to ideas of complexity and the openness, individuality and self-expression of contemporary living conditions. With their inherent sustainable and economic characteristics, contemporary wood products, fabrication and production methods can be used to generate site-specific designs as part of an ecologically sensitive building culture. While the architecture generated using contemporary CNC wood fabrication technology currently benefits from the import of technology and software developed in Europe, their application is not limited to revisiting familiar configurations, structures, and traditional joinery. Rather, in projects described here, contemporary fabrication technology provides a basis for design explorations specific to the economic and cultural context in British Columbia with its existing wood building culture and focus on sustainability and the natural environment.

While the design research projects illustrate concepts corresponding to the complexity of the context of design, they also highlight the limitations of translating abstract conceptual frameworks in material-based applications. Recognizing that “the key advantage of advanced technology” is to provide “greater freedom in the design process, rather than more flexibility or open-endedness in the finished product,”[5] the projects – consistent with their focus on contemporary wood building methods – acknowledge the particular characteristics of wood design and construction and point to an architecture grounded in the ecology of their extended context.

Endnotes

[1] see Easterling K. *Organization Space. Landscape, Highways, and Houses in America*, Cambridge and London: MIT Press, 1999.
[2] see Yeang K., “A Theory of Ecological Design”, in *Rethinking Technology*, Braham W. and Hale J. (ed.) London and New York: Routledge, 2007, pp.388-95
[3] see Leach N., Turnbull D., Williams C., “Introduction”, in *digital tectonics*, Leach N., Turnbull D., Williams C. (ed.) London: Wiley Academy, 2004, pp.4-12
[4] see Shea K., “Directed Randomness”, in *digital tectonics*, Leach N., Turnbull D., Williams C. (ed.) London: Wiley Academy, 2004, pp.88-101
[5] see Jones W. “Towards a Loose Modularity” Praxis, Issue 3, 2001, p.21