Limb: Rethinking Heavy Timber Joinery Through Analysis of Tree Crotches

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LIMB reconsiders historic heavy timber construction across cultures to develop new joinery methods by focusing on the natural occurrence of branch bifurcation in different wood species. Because of its low value, often the crotch of a tree is not harvested for commercial purposes. This project uses this vital element to design connections that replace traditional mortise and tenon or steel connections.

By replacing the joint with a single piece of wood that purposely grew for bifurcation in nature and moving the structural connection away from where vertical and horizontal members come together a stronger construction joint can be achieved. Beyond the reduction of waste and added value, this project has the following architectural ramifications:

1. Overall architectural design parameters relate to the natural angles of certain bifurcations. These restrictions have provocative formal implications.
2. A structural system that is scalable, from major tree bifurcations at the base suitable for larger buildings, to smaller bifurcations adaptable to furniture.
3. Different wood species sharing common structural capacities allow for cross-specie "crotches" as long as they share similar overall properties.

In the 17th century tree crotches were harvested for a variety of purposes from bracket systems in barn structures to structural joints in the construction of navy vessels (Encyclopédie Méthodique: Marine). In the 1960's renown modern furniture designers such as Sam Maloof replaced two part mortise and tenon joints in their chairs with a singular bifurcated piece increasing connection strength and producing more sinuous form. More recently Whole Trees Architecture and Architectural Association program directors Martin Self and Emmanuel Vercruysse explore organic form aggregation using entire tree branches with bifurcations.

Our research sets itself apart by assuming a syntactical approach to design. We are not interested in unique form generation based on unique parts, something that is very well explored in the realm of digital fabrication, rather are constructing a reusable language of bifurcated joinery. There are a number of common natural angular occurrences in limb bifurcations and we have reduced those to a set of parts that can be "tuned" to develop diverse structural systems. The two types of crotches identified are: the "r" and "y" type. We have designed a digital fabrication workflow that extracts standardized milled parts from an inventory of salvaged material. The cataloguing of recurring angles and other physical properties inherent to different species of trees allows for further development of the structural possibilities of this system, which can be applied to nearly any type of tree bifurcation allowing for infinite combinations within the language of bifurcated timber joinery.

LIMB develops four spatially optimized structural systems that leverage the "r" and "y" crotch connection: branching nested structures, hexagonal organic dome, three-way triangulated columnar structure and two-way triangulated frame. By elaborating on the natural occurrence of tree bifurcation as a tectonic element using contemporary digital practices and combining different wood species and diverse cultural traditions to propose new timber construction systems. LIMB is simultaneously global and regional in its approach.

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1. Overall architectural design parameters relate to the natural angles of certain bifurcations. These restrictions have provocative formal implications.

2. A structural system that is scalable, from major tree bifurcations at the base suitable for larger buildings, to smaller bifurcations adaptable to furniture.

3. New ways of connecting linear timber elements are developed beyond the "crotch" where cross-cultural scarf connections are revisited using digital fabrication.

4. Different wood species sharing common structural capacities allow for cross-specie "crotches" as long as they share similar overall properties.

Traveling through the Mid-Western landscape one often encounters weathered barns framed by expansive sky. These structures from a bygone time bear little resemblance to today's industrialized agrarian landscape. Much like the concrete silos that inspired Corbusier's modernist vision these wooden structures preserve the vestiges of a refined and pragmatic wide span building system developed through intimate knowledge of local materials and handcraft accumulated through generations of trial and error.

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LIMB develops four structural systems that leverage the "r" and "y" crotch connection:

1. Nest Structure. Spatially optimized parametric branching nested structure for occupiable space
2. Hex Dome. Spatially optimized parametric hexagonal organic dome with multi angular facets
3. Triangulated Column. Three-way columnar structure
4. Truss Portal. Two-way triangulated frame reminiscent of the traditional timber framing

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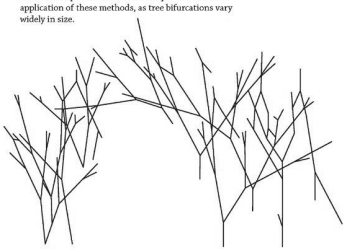
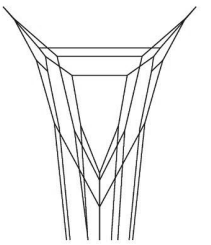
1. NEST STRUCTURE

A densely-built cluster like a hedge, of bifurcated joints connected directly to each other and to an orthogonal exterior shear panel system is hollowed out to form an inhabitable space. Scale comes into question with the application of these methods, as tree bifurcations vary widely in size.



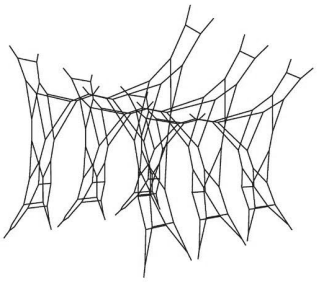
2. TRIANGULATED COLUMN

A larger structural element that mimics the joints that comprise it. The strength of the column is provided by triangulation of the members, and the exoskeletal shape could allow for inhabitation. This system can be adapted to scale of furniture.



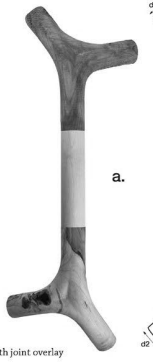
3. TRUSS PORTAL

An arched truss support which can support weight above and create enclosed space below. Triangulated and optimized truss systems allow for relatively lightweight wooden structures.

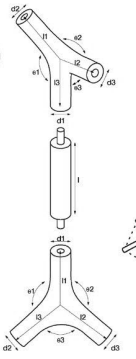


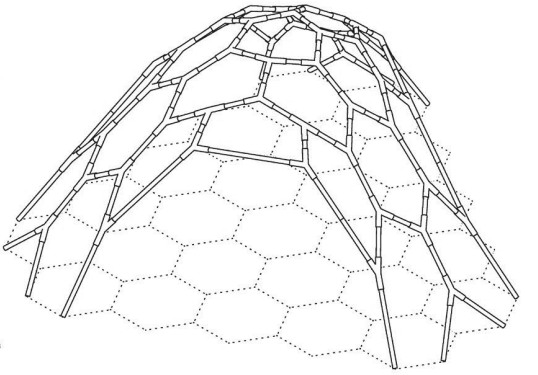
4. HEX DOME

The three-sided dome structure is comprised of hexagonal faces which are formed organically by the joinery system. Given the range of bifurcation angles in the inventory of salvaged logs and a series of other parameters such as entrance height and connection diameter, the tri-radial symmetry of the design requires three equal sets of joints which are milled from y and r-shaped logs. This process produces a need for out-of-plane angle in the joints, i.e. a curved node joined by straight connecting pieces. By producing a smaller and denser joint milled from the heartwood of a larger piece we can also achieve the curved shape needed. As a variant of the geodesic dome composed entirely from natural materials and optimized parametrically, the hex dome has potential as a structural element, allowing unique pieces to be integrated into a system that tunes their natural geometry as opposed to completely standardizing it.



a.



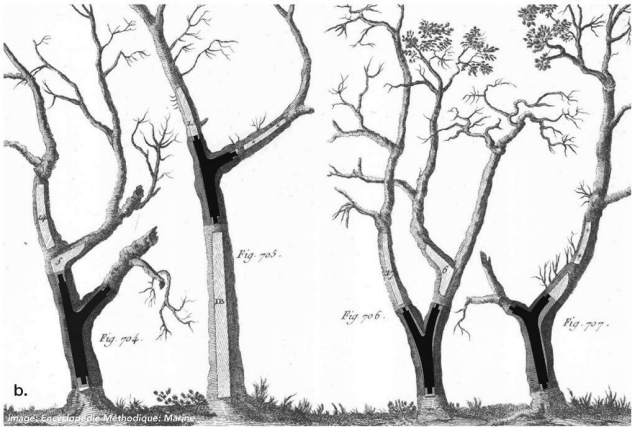


KEY

a. digital mockup of bifurcated timber joinery

b. 18th century Encyclopédie Méthodique illustration with joint overlay

c. CNC milled joint at 5-axis router



b.

Image: Encyclopédie Méthodique: Marine

c.