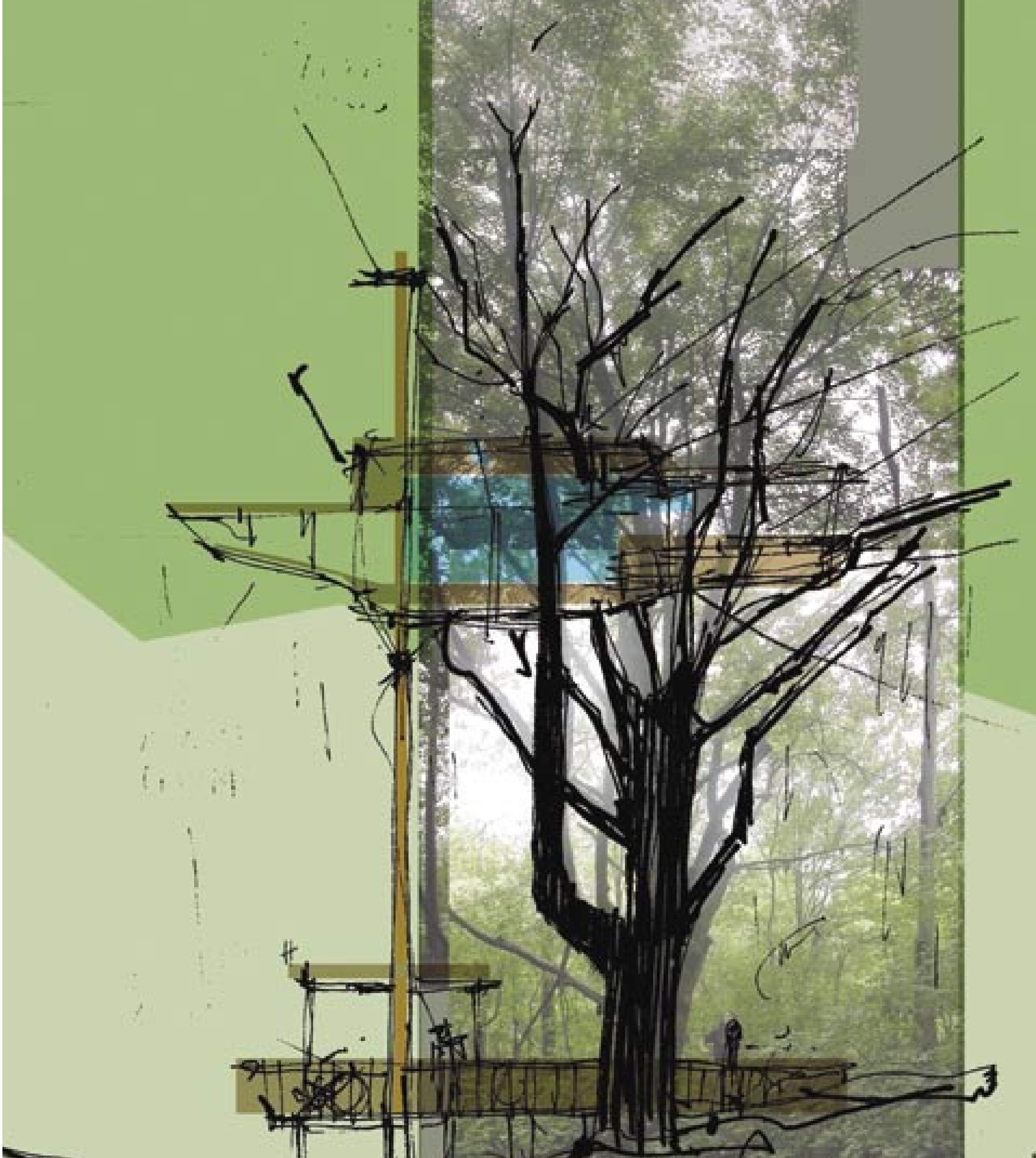
Branching Out

By Peter von Buelow

Structural steel supports a tree house designed for children with special needs.



Drawing by Kristine Synnes.

A steel tree, with a branching column of bent steel pipe, houses the Craig VanLaanen Tree House and Woodland Retreat in Mayville, MI. The tree house was constructed in 2004 at the Fowler Center for Outdoor Learning, which provides outdoor and educational experiences for people with special needs. The tree house was designed for the center's Trail's Edge Summer Camp, organized each year for pediatric ventilator patients at the University of Michigan C.S. Mott Children's Hospital. The 300 sq. ft house gives these children, about half of whom need wheelchairs, the opportunity to see the world from 22′ in the air.

The hospital has organized the camp since 1989. The first of its kind in the nation, the camp gives children who attend an opportunity to participate in outdoor activities from which they are otherwise restricted: horseback riding, hot air balloon rides, and even rides on a motorcycle. In 2002, a group of tree climbers set up harnesses that lifted campers into the treetops. The children were exhilarated by the experience of being in an environment that they had only seen before from the perspective of their wheelchairs.

After the 2002 summer camp experience, hospital representatives and camp staff met with faculty from the University of Michigan's architecture program to discuss development of a structure that would allow children with limited mobility to experience the height and excitement of spending time in the trees. Members of the architecture faculty worked with graduate students to explore ways to place a house in a tree.

The image of a ship sailing through the treetops was an early part of the concept for the tree house. The challenge was supporting the house in a way that would allow it to "float" among the branches. After consulting an arborist, it was decided that the house should be held completely independent of the elderly red maple that had been chosen as its berth. A wooden pole structure was briefly considered but rejected on the grounds of the static appearance of "table leg" supports.

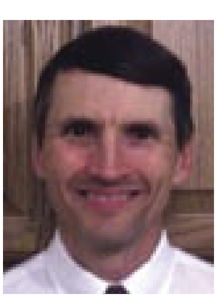
In the end, the solution was to design a second "tree" capable of carrying a house. The structure would have to bend and twist in the form of a tree and be able to support the weight of the house on the tips of its extended branches, a design that lent itself to steel.

A branching column was chosen as the structural support for the tree house because of its obvious allusions to natural trees and to give the structure a unique and playful character.

Starting from a base of bundled round pipe sections, members divide at nodes into two or more continuing members. With this outward branching, the number of members increases as they spread out from the origin. Many small "twigs" collect the load and funnel it back to a single support.

Normally, branching systems are loaded only at the ends of the outermost branches and transmit the collected load back through the nodes to fewer and fewer members until a single support is reached. At Trail's Edge, however, poor soil strength and the cantilevered load produced by the tree house prompted the design team to design a structure that branched both upward and downward.

The geometry of the tree house was also determined based on the restrictions of the site. Part of the house structure is nestled among the branches of the living maple tree. To avoid damage to the root system, the branching column's foundations had to be placed to the side of the maple's trunk, while the upper portion of the tree house extends through its branches.



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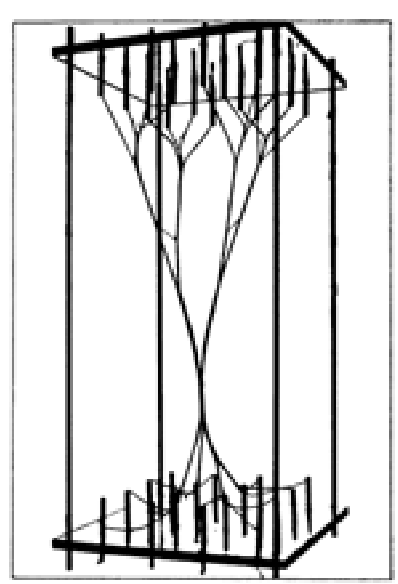
Geometry of a Tree

Thread models use cohesive threads to generate branching geometries. In this design exploration technique, slightly over-length threads are fixed between end points. The entire model is then dipped in a liquid solution and removed. The threads pull together by surface tension to form a branching geometry. This technique can be applied to two- and three-dimensional models, and the generated forms can be controlled to some extent by the amount of slack placed in the threads. The geometries are not entirely unique, particularly when many threads are present, but they do supply a suitable initial form that can be improved with successive analysis.

Similar techniques were employed for the form finding of the tree house. Several thread models were made to explore the placement of the main column and angles and placement of the branches. Study models were made with tensioned cotton threads, and then dipped in resin upside down to set a permanent form. After finding a trial form, the geometry from the thread model was entered into a 3D AutoCAD model. From this format, the geometry data could be electronically manipulated and read into STAAD.Pro, which was used for the finite element analysis. By going back and forth between the STAAD models and AutoCAD 3D models, the structural results were rendered in 3D to assure that the load-bearing requirements, interference criteria, and the formal intentions were all met.

With the geometry designed and analyzed, the design team built a 1/2" = 1′0" (1:24) structural model to check the behavior predicted by the analysis. The tactile understanding of the loads verified the STAAD analysis. The model was also useful in communicating the form of the column to the fabricator.



Model: Peter von Buelow

Three different round sections were used to create the steel branches of the tree. Photo by Peter von Buelow.

Branching Column Connections

The detailing of the tree house, particularly the pinned connections and bundled base, was influenced by the design of the branching columns of the Stuttgart, Germany airport terminal, designed by Frei Otto at the Institute for Lightweight Structures at the University of Stuttgart. A major innovation in the Michigan column structure, however, can be seen in the treatment of the nodal connections. Rather than cast connections as used in other examples, the branches in the tree house are joined by continuous radius bent pipe. This results in more tree-like connections and better evokes the image of a tree. The eccentric placement of the central column in response to the hoisting point of the tree house also changes its support requirements at the base.

The pipe members of the tree house were sized to carry both the environmental code loadings for Michigan as well as some not-so-typical live loads. In order to accommodate the lifting of visitors into the tree house, the designers incorporated a hoisting point into the top of the column and centered it above the entrance. To carry the eccentric load of the house itself, the design team chose steel Hollow Structural Sections as both an economical and versatile material for the connection detailing. The team decided to construct the branching column using continuous steel HSS, rather than the more typical discrete nodal connections. In concept, the HSS steel was treated much in the same way as the threads of the initial trial models. The team designed the pipes as continuous elements from top to bottom. Where the pipes come together, they form bundles, which were welded full length. The design of the pipe sizes strikes a balance between criteria of stiffness and minimum bend radii, as well as economy of size. The three sizes chosen fulfilled these criteria and were compatible with the fabricator's capabilities.

After preparing the shop drawings, the steel fabricator cut, bent, assembled, and welded the tangled pattern of branches and roots. The fabricator also delivered and aided with the erection of the steel column. With a 40′-tall column in a wooded site with limited access, the on-site assembly had to be carefully considered. For ease of transport, the fabricator split the tree at mid-height and welded sleeve joints into the pipe sections for precise reassembly on site. The section of the mast above the deck of the tree house was also sleeved and site-welded. The attachments at each end of the branches were pinned to the tubular frame deck, which became the base of the actual "house" portion, resting above the branching column.

The Craig VanLaanen Memorial Tree House and Woodland Retreat was a community project that took nearly two years to complete. The cost of materials was around $88,000, but labor throughout the design, analysis, fabrication, and construction phases was donated. A wide range of professionals volunteered to make the tree house a reality for children who were finally able to leave their wheelchairs behind as they soared upward to their own place the treetops. ★

Owner
Fowler Center for Outdoor Learning, Mayville, MI

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Structural Engineer & Detailer
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Engineering Software
STAAD.Pro 2004

Detailing Software
AutoCAD

Funding Agency
University of Michigan C.S. Mott Children's Hospital, Ann Arbor, MI

Because of poor soil conditions at the site, the tree branches downward (as well as upward) to counteract the eccentric loading of the tree house. Photo by Peter von Buelow.