The Robot-TreeHouse: STE(A)M Education and Digital Fabrication

Tree House

A tree house, a free house,
A secret you and me house,
A high up in the leafy branches
Cozy as can be house.

A street house, a neat house,
Be sure and wipe your feet house
Is not my kind of house at all –
Let’s go live in a tree house.

— Shel Silverstein [1]

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BACKGROUND / OVERVIEW

Design/build has been part of architectural pedagogy for around 50 years, and it has always seemed to exhibit symptoms of a split personality. At its best, it is a hybrid beast, comprised simultaneously, or sequentially, of both design exploration and pragmatic application. For three generations it has also represented a unique chance for architecture students and faculty members to metaphorically ‘live in a tree house,’ rather than the ‘street house,’ the ‘neat house’ of mainstream architectural education. Offering opportunities to get our hands dirty and to experiment with new tools and materials, design/build challenges us to go out on a limb. And to make the adventure even more exciting, we’ve generally taken others out on that limb with us. One of the most outstanding aspects of design/build has always been the opportunity to work with various ‘publics,’ like community organizations, housing advocates, gardeners, school children and other groups.

A central aspect of the design/build ethos is the opportunity for ‘hands-on’ work, stressing on-site construction experiences, the direct use of hand- and power-tools, and an emphasis on materiality. Given the centrality of this ‘hands-on’ ethic, it is perhaps not surprising that new digital tools like parametric modeling and Computer Numerically Controlled (CNC) fabrication, which threaten to interject a robotic intermediary between the hand and the work, are slow to be adopted in many design/build programs. But given the inherently experimental opportunity that design/build projects offer, these seem ideally situated as the best venue to test new digital tools and techniques in architectural education. Many programs are working to integrate new technologies –or perhaps to further hybridize the split personality of design/build –by inserting digital design and fabrication into the mix. But ‘digital’ an ’design-build’ still seem to be uncomfortable partners. The Robot-TreeHouse

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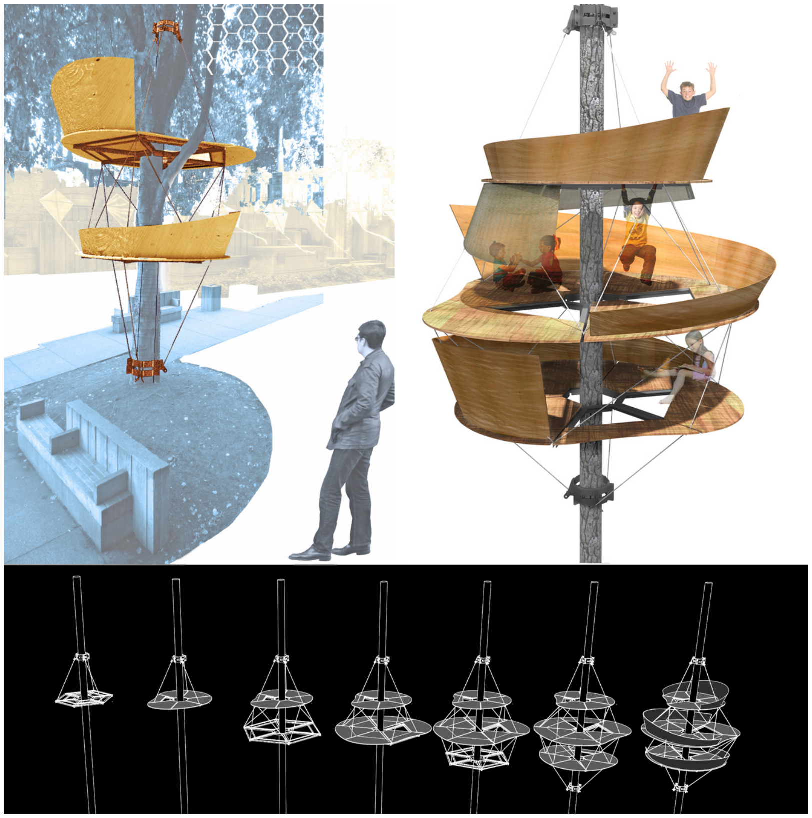

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Figure 1: Elementary students' design charrette

Figure 2: University students' design ideas for the Robot-TreeHouse, including installation diagrams

project is an experiment in hybridizing digital and physical design and construction. Its overt goal, as I will elaborate, is to address STEM education (Science, Technology, Engineering and Math), and to inspire elementary school students' imaginations in the fields of design and fabrication. Another underlying motivation for this initiative is to take design/build pedagogy even further out on a limb by making digital design and fabrication central, rather than peripheral, to nearly all aspects of the project.

The Robot-TreeHouse initiative was co-founded by Rob Corser of the University of Washington's Department of Architecture (UW); Les Eerkes, a Principal at Olson Kundig Architects (OKA), and Hans-Erik Blomgren, an Associate at ARUP's Seattle office. All three had worked with students of various ages previously, but none had tried to integrate professional research, university teaching and K-12 education before. This project aimed to address all three areas of teaching and research by bringing together design professionals, university students and elementary school children to imagine and build something so simple, but so loaded with potential: a tree house for the 21st century.

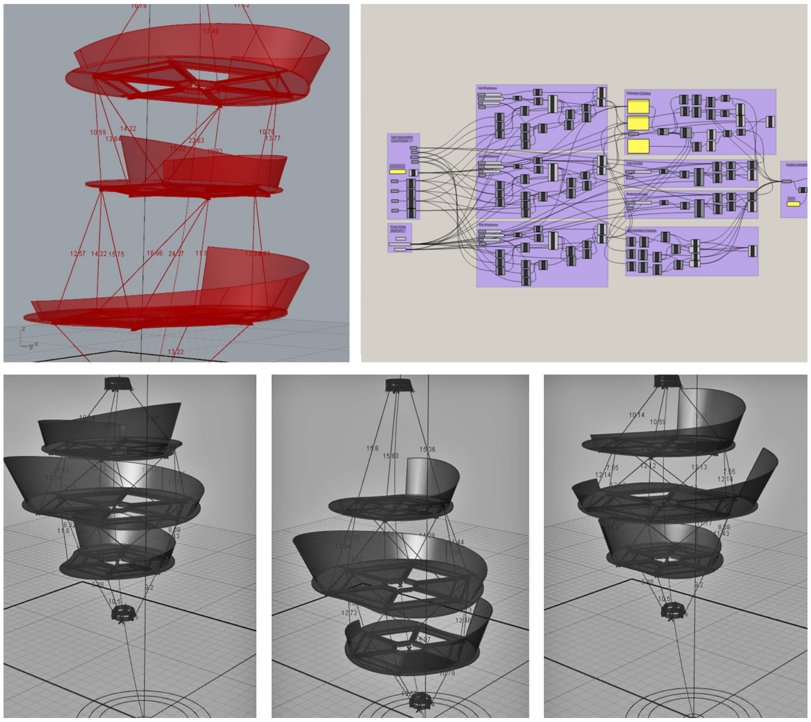
With both funding and participation by UW, OKA and ARUP, the project's first phase was organized as an eight week vertical design studio at the University of Washington during the summer of 2013. Five graduate students and five undergraduates formed the core design and fabrication team, and they worked with a group of twelve elementary school students as their clients. The project aimed to explore the concept of the tree house in innovative ways, and to use digital tools to further engage with the youngest generation of 'digital natives,' for whom the concepts of 'robot' and 'tree house' are rarely combined, but equally compelling.

DESIGN CHARRETTE WITH ELEMENTARY SCHOOL STUDENTS

The university students' first challenge was to organize a charrette intended to get the elementary students engage with, and contributing ideas to the project. The charrette was scheduled for a Saturday morning, during which the younger students were introduced to digital design and fabrication tools and taken though a series of individual and small-group design exercises. (Figure 1) The group ranged in age from 8 to 12 years old, and was almost equally comprised of girls and boys. In an introductory exercise they were encouraged to list the first words that came to their minds when thinking about what a tree house might be, .what a robot might be, and finally, what a hybrid 'robot-tree house' might be like. They were asked to use large-scale printouts with images of trees to draw on, paint and collage a robot tree house. After discussing their words and images, the kids were organized into teams of two and given small scale model 'trees' (made of broom handles and sticks, etc, mounted to wood bases), as sites where they were asked to model their ideas with pipe cleaners, cardboard, popsicle sticks, glue, paper and tape. The resulting sketch models were rich with potential program, including slides, swings, hideaways, and a plethora of digital features like wall-sized projection screens to skype with their friends. The most resonant aspects for the university students were not the overtly 'digital' ones–like the skype screens - but the more poetic aspects, like the fact that most of the young clients' model tree houses hung by tension cables from the tree, rather than resting on limbs or directly attaching to the tree trunks. The 'robot' aspect of the prototype tree house wouldn't address embedded technologies (although this will probably be something for future prototypes), but rather, the university students wanted to engage with the rich potential that digital (i.e. robotic) tools could provide for making a light-weight, flexible and inspiring tree house system that could be hung from almost any tree in a variety of different ways.

RE INTERPRETATION AND PROTOTYPE FABRICATION

Following the design charrette, the university students worked in teams to reinterpret the younger students' ideas and to propose two unique approaches that were presented and tested at full scale in a tree outside our fabrication facilities. This quick process resulted in two viable schemes. The winning proposal focused on clamping a collar high up in the tree and using steel cables to support a series of wood compression rings assembled around, and suspended from the tree trunk below the clamp. (Figure 2) This approach is able to weave itself around limbs, to adjust to non-vertical (i.e. angled or curving) tree geometries, and to augment the tree's structure without obscuring the essential nature of trunk and limbs. The initial design work was done with simple digital models and small scale laser-cut prototypes. After further discussion with clients, professionals and faculty, the university students refined this approach digitally, and developed a detailed construction strategy that was based on a hexagonal framework of steel angle components that are adaptable to various tree diameters and heights. The system is pre-fabricated of trapezoidal sub-assemblies that are bolted together around a tree trunk, and suspended from clamps by quarter inch diameter steel cables. The resulting hexagonal steel angle frames are clad with digitally fabricated three-quarter inch Baltic birch platform elements that reinterpret the hexagonal geometry of the sub-frames as sinuously curving edges for the platform floors. Three variations of hexagonal steel frames, varying in diameter from 6 to 8 feet, were designed and prototyped. A single plywood jig was digitally produced to assist with the repetitive layout and clamping of steel angles used to weld up the trapezoidal frame sections. The use of digital data to guide the manual operations of cutting, drilling, clamping and welding of the sub-frames was just one example of the reciprocity of computers and hands in this project.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Another distinctive aspect of the Robot-TreeHouse is the parametric variability of the composition of platforms: with different possible sizes, orientations and distributions vertically along the trunk of the tree. University students worked with Grasshopper software to develop a parametrically variable model of the Robot-TreeHouse that encodes a wide range of possibilities for this system to adapt to different trees, sites and programmatic activities. The digital model (Figure 3) allows for the Robot-TreeHouse system of platforms to be installed on almost any tree (or telephone pole) with platforms organized around whatever rotational angle that might be desired for that site. The order of installing the platforms can also be varied and their spacing adjusted depending upon the specific constraints and tree geometries for the chosen installation site.

The system's adaptability was conceived and worked-out conceptually long before being encoded digitally, and it became a core of the design's hoped-for adaptability. Modeling the system's range of potential variation in Grasshopper was a significant challenge. What the students eventually produced was a Grasshopper definition that is based on a 3D mapping of the tree trunk. By surveying a tree's vertical geometry (height, diameter, angle, curvature, etc) a spline is imported into the Grasshopper definition as the starting reference curve. The definition then allows users to set the height for the top and bottom clamps around the trunk, and the height, order and rotational orientation of the three (or fewer) platforms. The Grasshopper definition then calculates and reports the cable lengths required to accomplish the desired installation. Because the three-dimensional geometry is entirely defined by the lengths of the tension cables, almost any desired composition can be achieved, and almost any shape of tree (curved, angled or vertical) can be accommodated.

Figure 3: Grasshopper parametric model of the Robot-TreeHouse prototype with variations

By contrast, the edge curvature of the three-quarter inch plywood decks for each level was developed intuitively. Students modeled various geometries, prototyped them at small scale on the laser cutter, and discussed the results in order to come to a final language. Flowing curves were laid out that either closely followed the edge


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of the hexagonal steel sub-frame, or cantilevered as much as 16 inches beyond the edge of the steel. To provide enclosure and cozy seating for each level, the students designed curving backrests that slot into the edges of the platforms. These back rests were designed to be segmental, and to have sloping top edges in order to vary the amount of enclosure offered. To accomplish the needed three-dimensional curvature, the backrests were designed to be fabricated from two layers of one-quarter inch Baltic birch plywood. The three-dimensional surfaces were modeled in Rhino and unrolled to produce flat sheets for fabrication. Theses subtly different plywood sheets were then glued and clamped to laminate together, with their tenons inserted into the edge slots of the platform floors for curvature control. (Figure

Figure 4: Digital and hand fabrication of curvingplywood surface components

4) The direct use of digital tools in the fabrication process might be most evident in the ability it offered to design curving and bending surfaces, to unroll them, and to make flat patterns that could be cut out and reassembled into three-dimensional forms. But the ability to accurately cut, drill, lay out, clamp and weld all of the trapezoidal steel sub-assemblies for each platform was equally important to the project's success.

PROTOTYPE INSTALLATION

Among the major challenges that were anticipated but not fully understood during the design process, was the logistical and physical difficulty of hoisting each platform's hexagonal steel frame into position on the tree. The three-part top collar was bolted around the trunk about 18 fee above the ground without much difficulty. The first of the three platform frames was easily bolted together around the trunk at ground level, and ropes attached for hoisting. But the hoisting process was much trickier than anticipated. Ropes slipped from pulleys and snagged, and the frame dragged against the tree trunk. We eventually produced push sticks to aid in the stabilization and control of the frame during erection. After several tries with ropes and sticks, the platform was finally in place, and the steel cable supports installed, adjusted and tightened. Using ladders and climbing gear, students then hoisted the plywood floor elements and bolted them onto the steel frame. At the end of day one, a single platform was suspended high in the tree. The second and third platform's frames were easier to install, by virtue of the first day's experience and the fact that, working from top to bottom, they were closer to the ground to start with. Having all platforms installed, the finishing touches included the installation of the curving back rests, and stabilizing the overall system by installing the bottom collar and tensioning the remaining cables.

EXPERIENCE AND LESSONS

The Robot-TreeHouse prototype was first installed on a pine tree at the edge of a fenced open space adjacent to a busy urban street. Platforms started about four feet above the ground, with about four feet between each of the three platforms. One open floor bay on each platform allowed users to climb up from the ground and then from level to level. Adults could easily clamber from one platform to the next, and most kids could hoist themselves up and through with little difficulty. On each level smaller kids could stand up and walk around, and bigger ones (adults too) could easily scoot around and sit comfortably. Future potential installations will experiment with different vertical spacing, made possible simply by changing the length of the steel support cables used. While only twelve feet above the ground, visitors to the top platform (the smallest one –sort of like a crow's nest) felt quite high up in the tree. The elementary students reported that the Robot-TreeHouse looked "cool," felt "like a swing," and made them think of a "spaceship." They were so eager to explore, swing, and make the tree house their own, that conversation with adults quickly became irrelevant. (Figure 5) While one of our intentions was to include the youngsters in as many aspects of the project as possible, busy summer schedules and liability concerns largely kept the elementary students out of the fabrication shop, and they had to stand well back from the more dangerous aspects of the hoisting and installation. Once completed and inhabited however, the Robot-TreeHouse provided both visible and implicit lessons in structure, stability, geometry and construction.

For the University students, the lessons of the Robot-TreeHouse project were many and varied. A key realization was the inherent difference in experience between a 'tree house' and a 'street house.' Immediately after the initial design charrette, the


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students understood that inhabiting a tree house offers the opportunity to turn our typical expectation of gravity on its head. Rather than building upward from foundations planted firmly in the ground, a tree house can suspend itself, inverting the typical load path of compressive structures, in order to swing more freely in tension – to literally 'hang out' in a tree. This realization was always at the core of the Robot-TreeHouse project. Summing up both the formal inspirations and experiential qualities of the tree house, one of the university students said: "the Robot-TreeHouse's poetic form is inspired by the dialogue between the organic shape and the geometric order of a lily pad. The magic of the tree house's tensile structure lays

Figure 5: Installation and testing of the first Robot-TreeHouse prototype

in how it responds to bodily movement. As one leans on the curving backrests and changes the balance of the whole structure, one feels the gentle concentric sway of the platforms. Thus, the Robot-TreeHouse allows for a personal and intensified connection to the tree, and to the experience of gravity." The poetic potential of architectural technology is evident in this subtle responsive movement. It is this gentle swaying that fulfills the childlike dream of an autonomous expressive space, free from the ground and up in a tree. While there is no ”robot” literally present in the final built form of this prototype, digital design and robotic tools were crucial to creating the formal and experiential qualities of the tree house. While the Robot-TreeHouse contains many examples of science, technology and mathematics in action (geometry, gravity, stability, triangulation, digital fabrication ,etc.), it is perhaps its more poetic experiences of engagement with the built and natural environment that provide the most compelling and memorable lessons.

REFLECTIONS

Among the most pressing educational agendas in the United States today is to engage young students in Science, Technology Engineering and Math (STEM). The arts, including architecture, have an emerging role to play in energizing this agenda, and transforming STEM into STE(A)M. The Robot-TreeHouse project is aimed directly at inserting (A)rchitecture into this mix in a compelling way. As a new kind of collaboration between a major university architecture program, an internationally acclaimed architectural practice, and a leading engineering firm, the Robot-TreeHouse project explores the possibility of playfully integrating STEAM education with advanced digital design and fabrication. “Robot” and “tree house” are both concepts loaded with meaning for children and adults alike. These words were the launching pad for their imagination and the beginning of a design process. Prompted to describe a Robot-TreeHouse, young school children were given a room full of drawing and modeling supplies to develop their ideas and vision. The charrette’s results were carefully documented and they formed the seed for ten undergraduate and graduate architecture students to design and prototype a full-scale Robot-TreeHouse in only seven weeks.

The ultimate goal for the project was to engage young people in the observation of their environment, and to spark their imaginations about architecture, geometry, engineering and fabrication. The Robot-TreeHouse was designed for adaptive deployment in the forests of urban and rural parks or for installation on a telephone pole downtown. The first prototype was realized through sophisticated computer modeling and digital fabrication. Students, both elementary and college aged, were given access to advanced analytical and fabrication tools, and they saw first hand how the digital world that computer games are based in can generate a physical space in which to play, observe, and engage with the world.

The project’s many objectives were mostly achieved, but with strong promise for future elaboration and refinement. The university students demonstrated the ability to employ advanced digital modeling and fabrication tools and to put them to use in a sophisticated and ambitious structure. But the impact on the imaginations and educations of the youngest project participants is harder to measure or assess. Future installations of the Robot-TreeHouse might be augmented with specific lesson plans aimed at demonstrating basic mathematical, geometric and physics lessons. And the Robot-TreeHouse can certainly be re-installed in other natural settings, with the goal of connecting young students to ecological lessons only possible by getting outside the classroom and climbing a tree. While much of the project’s potential remains to be developed, everyone involved, from school kids to university students, faculty and professionals, all found themselves positively transformed by having taken this opportunity to go out on a limb.

In her recent book, *Modern Life*, (finalist for the National Book Critics Circle Award), author Matthea Harvey describes what have been called 'devastated worlds' and 'hybrid forms of life.'[2] A series of her poems is dedicated to 'Robo-Boy' –whose struggle, as the author describes it, is: "being half-machine and half-human." Robo-Boy's hybrid existence roughly parallels the experience of aspiring architects and young people today. In their everyday lives, today's kids are challenged to navigate a world that is both technologically mediated and a physically embodied reality.

Except for an inevitably ad-hoc quality, the tree houses of their dreams probably don't look much like those of my youth, made as mine were of discarded packing crates and bent nails. Among the tools, materials, and cultural references available to these contemporary tree house builders are a slew of digital design and fabrication tools that were practically unimaginable two or three decades ago. The Robot-TreeHouse is a hybrid beast, designed and fabricated with hands and computers. But it is a new tree house that eschews nostalgia in order to tap into emerging potentials available to, and resonant with, the digital natives who are increasingly entering our design studios. To make architecture that is relevant for current and future generations, it needs to keep pace with the dream worlds and the lived realities of a technologically infused culture. This doesn't mean sacrificing long-standing values like community engagement, direct experience, materiality or hands-on education. On the contrary, the challenge of a design process that is increasingly digital is precisely to open it up to all of these agendas.

ENDNOTES

1. Silverstein, Shel. *Where the Sidewalk Ends: The Poems & Drawings of Shel Silverstein*. New York: HarperCollins, 2004.
2. Harvey, Matthea. *Modern Life: Poems*. Saint Paul, Minn: Graywolf Press, 2007.