Fig. 1: Mobile Orchard. View of animated lights encircling tree at night, Finsbury Ave. Square. (Photo by Alex Haw / atmos)
THE MOBILE ORCHARD:
GROWING ERGONOMIC, EDIBLE, AERIAL DATASCAPES

ALEX HAW

The Mobile Orchard is an inhabitable public art installation by the art/architecture practice atmos, commissioned as the centrepiece for the City of London Festival 2013 to highlight the decline in British orchards. The digitally cut, laminated timber structure celebrates the urban fruit tree, welcoming visitors to a varied landscape of occupiable spaces arrayed around a sculptural central spine. It utilised a sophisticated parametric design model to control a complex range of inputs and systematically feed thousands of individual components to the CNC router, and onwards to assembly. This text explores the project’s genesis and illuminates some intricacies of the multilayered fabrication and installation process.

THE UNWITTING ARCHITECT
‘The best friend on earth of man,’ wrote Frank Lloyd Wright, ‘is the tree. When we use the tree respectfully and economically, we have one of the greatest resources on the earth.’ Yet the tree, provider of that most ubiquitous and economic of building materials, is also the contemporary architect’s arch enemy: effortlessly graceful in its stretch from soil to sky; humiliatingly all-encompassing in its integration of form and function; unsurpassed in its economy of means, unparalleled in its management of budgets; defiant and exuberant in its unstoppable, muscular, florid will to form.

Trees’ structural diagrams are of such extraordinary (and elusive) efficiency that they alchemise timber into steel, even in apparent defiance of logical loading routes. Their branches wriggle outwards in unrestrained creativity, yet still sate the most exacting of briefs. Their leaves maximise surface area with the most minimal of means. Their welcoming roots (think Newton’s cradle) have changed the very course of scientific history — and engulfed World Monuments: think Cambodian figs at Tra Prohm. Their environmental collaboration with symbiotic ‘tenants’, their fertilisation by local hand-maiden fauna, and their reliance on hidden soil fungi, all taunt individualist humanity with a future-thinking model of ecological cooperation.

ARBOREAL ALMANACS OF DESIGN
It was a gardening journalist, Walter B. Hayward, writing for the New York Evening Post in 1913, who preceded Frank Lloyd Wright’s famous other quote on trees, and said on the saving grace of vines: ‘Some day the American Institute of Architects will get together and vote a solid gold medal, summa cum laude, to the man who invented vines; for it was he who made the architect’s profession safe.’ Planners and urbanists seem all to agree: trees heal the wounds inflicted by buildings, softening their sharp corners, foliating the flatness of their inarticulate facades.

In an age of algorithms and emergent digital design, the complex growth patterns of nature’s closest thing to architecture, whilst also its most radical engineer and its most inventive geometer, demand investigation and sincere attempts at flattering imitation, offering, as they do, deep lessons in a wide array of architectural issues, spanning culture and technology.

BUILDING A TREE
The City of London Festival is an annual event that activates the hidden spaces of the corporate capital with cultural content. It also increasingly pursues an environmental agenda that promotes biodiversity within the crystalline caverns of the city’s architecture.
In 2013, the city commissioned atmos to design a ‘Mobile Orchard’, which would thematically explore the role of trees in the city, the decline of British orchards, and the disappearance of the urban fruit tree (fig. 2). Like a wind-borne seedling, the Mobile Orchard was to travel to five separate locations within London’s Square Mile, introducing tight logistical requirements for rapid breakdown, transport and re-assembly.

DESIGN SEEDS
An inhabitable tree, tailored to the ergonomics of intrepid users, a structure that would welcome and embrace, encouraging exploration and relaxation, cross-fertilising nature and architecture in ways every bit as artificial as their urban-tree referent; splicing, grafting, pruning and re-engineering raw matter to construct a labyrinth of branches that would indiscernibly double as steps leading to a constellation of aerial seats and sky-thrones.

Early designs investigated the use of thin stainless steel sheet, V-folded along curved lines using developable surfaces, creating long filigree spans with minimal use of material while emphasising a crystalline artificiality that reflected the local architectural palette and the engineering prowess of trees themselves.

ARTIFICIAL GRAIN
Budgetary and comfort issues governed a switch to the flesh of trees themselves, and a design that developed its own form of timber grain — ironmongery — its only recourse: steel. The tree’s emphatically horizontal (and thus accessible) limbs were to offer and bear the hardiest and most sturdily-packaged of fruits, apples, that a wary public were likely to feel comfortable to pick and eat, and one they would most readily symbolically associate with a British orchard.

Fabrication negotiations led to a design layering 4 mm slices of glued Latvian birch plywood, chosen for its economy, strength and durability. This lamination of laminations created a rigorously parallel series of stripes and striations that fortuitously recalled the ‘straight, fine, uniform texture’ of vernacular apple and cherry hardwoods. The differentially torqued bolting technique, required to further bind the plywood sheaves, counteract shear, and resist splitting or overturning as they deviated from their centreline, similarly mimicked the way hardwood ‘pulls’ leaning stems into alignment through the development of ‘tension wood’ (fig. 3).
The core design centred on a trunk that leaned and cranked and bent and spiralled, and generally twisted as far as engineering constraints would allow such a structure with a deeply eccentric centre of gravity, a vulnerability to sudden gusts of fierce wind at the base of its host towers, and the challenge of mobile live loads tracing their aerial paths across its aerial branches. The trunk had 12 trunk segments of 30-degrees (their edges thus simply machined by a 15-degree CNC bit) (fig. 4) bundled against an asymmetrically-spiralling series of diminishing ellipsoidal compression tree-rings, to which they were tensioned and glued. Like trees in general, it had a severely limited budget, and thus deployed the minimum material needed, arraying slices of only 50 mm width into the shallowest shell possible thus encasing a central void which could be visually surveyed by those that leant across its base and dipped their head into a hole that exploited a pocket of local structural redundancy.

The structure originally had, like most trees, a generous fanning array of undulating, elongated roots that multi-tasked as welcoming street-furniture and buttressing supports. When budgetary constraints amputated their extensions, the base

**ECCENTRIC SPIRALS**

*Fig. 4: Separated trunk-slice segments awaiting tethering together. (Photo by Alex Haw/atmos)*

*Fig. 5: Assembled, denuded trunk core being lifted for transport to first site. (Photo by Alex Haw/atmos)*

*Fig. 6: View past lowest tree ring into the void of the trunk base, without ballast. (Photo by Alex Haw/atmos)*
of the trunk was forced to evolve into a separately bolted void (fig. 6) that could incorporate over 1.5 tonnes of ballast, which had to be removed for transport. The tree ultimately relied upon a sole central shadow root for its stability — a mutant echo of the real-world adventitious stilt, knee or buttress roots that more typically intermesh to form rigid support to the structure above.6

**PARAMETRIC THICKET**

The trunk’s complex spiralling geometry governed each segment’s capacity to generate branches; each extension fighting both for limited local purchase and fluid incorporation in the global constraints of optimised stair paths and head-height enclosures. Each branch needed to be removable for transport (fig. 7), and so its structural connection back to the trunk was reduced to the simplest possible essence; a protruding resin-anchored threaded rod traversing the trunk void, which was then wound tight against the shell opposite, its highly-torqued nut then concealed by the overlay of an LED strip.

The junction between trunk and branch entailed a 2-fold flaring-plane socket detail that ensured the branch could be socketed against the meat of the inner rather than outer trunk, the angled tolerance of its outer taper allowing for the timber’s expansion and contraction from heat and humidity. The fading array of bolts along each limb assured its life, much like the punctuation of bark’s gas-exchanging lenticels.

The branches wound outwards and upwards and bifurcated, spliced with lighter laser-cut slices of S-shaped aluminium (strengthened using curved folding), referencing both arboREAL uses of folded strengthening, and the binary materiality of bark and core.

**LONDON LEAVES**

The canopy, like trees themselves, was subject to a strict budgetary constraint, thus developing a leaf design that doubled shading with information (that great unifier of natural and financial systems); each leaf outlined a local London Borough, each shape thus perfectly tiling without waste onto laser-cut sheets, maximising material surface spread whilst providing visitors with local cultural reference (fig. 8).

Its phyllotaxy hybridised common fruit-tree leaf types, alternating distichous7 with verticilate,8 since spiral arrangements became impossible along the enforcedly 2-dimensional axis of the secondary branches. The petiole (or stalk) expanded each borough boundary into a meaningfully wriggly line that balanced maximum extension, and thus avoiding auto-shading, with minimum viable strength; a single, central, veinlike fold on each, hand-pinched in seconds, and thus afforded further structural stability.

The collection of borough outlines, varying widely in geographic area, reflected the variance in leaflet blade size of many compound leaf types, with each ‘London Leaf’ lamina also varying widely in appearance, from ovate to semi-elliptical, orbicular to perfoliate.9
SCRIPTING NATURE

The design process was developed almost entirely using Grasshopper and RhinoscriptVB (fig. 9), where an ever-expanding ecology of interdependent tools were built that simulated the artificial growth of trees at a range of scales. The scripts enabled the management, automation, rationalisation, subdivision, contouring, slicing, separation, numbering and preparation of parts into geometries that could be categorised, separated, routed, assembled and physically realised (fig. 10). The system steadily aggregated enormous levels of unprecedented complexity, constantly informed by engineering, ergonomic, economic, fabricational and logistical inputs and iterations.  

The network of forking branches required iterative geometrical testing to seek maximum spread with minimum ingredients whilst incorporating randomised switches of direction, with varying intensities of 3D curvature and bifurcation, each toggled to optimise local coverage (fig. 11). Planometric deviation was limited by structural capacity, whilst sectional genesis was governed by ergonomics, secondary-branch geometries and tertiary foliation. An extensive array of drivers and constraints thus generated a deeply rigorous relationship between root and trunk, branch and leaf, all centring on a single, all-inclusive parametric definition.
LUMINOUS XYLEM

Trees generally appear to be the epitome of static nature, monumental and immutable – yet internally, they bristle with electricity; they can trigger startlingly rapid movements through nerve-like electrical impulses. The physiologist John Burdon-Sanderson first noted botanical electrical signals in 1873 whilst studying Venus Fly Traps, and science has since documented (with notable recent upsurge) the pantheon of sensitivities of various forms of plant life, including swift signal response and transduction.

The limited gestation period of the Mobile Orchard forbade development of sophisticated tactile thigmomasty though it incorporated a DMX-programmed version of photonasty; its bark echoing the surrounding public clocks by responding to the fluctuation of light across the day. Long 16 mm wide strips of linear LEDs, IP-encapsulated in sap-like silicone, excavated a perfect quartet of plywood slices (fig. 12), their linearity emphasising the bundled fibrosity belying all trees, their segments illuminating in accelerating chronological sequence, rotating in a slow crescendo that climaxed with a cataclysmic hourly chime. The tree’s dead matter was thus enlivened with live data, just as trees coalesce living and sloughed-off matter.

The continuous presence of light – the phototroph’s core fuel – alluded to the city’s own unceasing nocturnal rhythms, and its factory of productivity, whatever the hour (fig. 1).

FABRICATION PROCESS

The manufacturing hybridised a range of subtractive technologies (3D-axis CNC routing with water jetting and laser cutting), working with one of the only CNC operators in London that also operates as a fabricator and contractor. The initial design specified 18 mm plywood sheet, ubiquitous and by far the most economic per weight, monolithically CNC-contoured in 3 mm steps, but prototyping revealed that the necessary flipping and under-cutting required for rounded 3-dimensionality catastrophically undermined the vacuum suction of the machine bed, prompting the switch to thinner slices cut rapidly from a single side only. The project’s virtual geometries necessitated close collaboration and feedback between designer and fabricator, particularly in the refinement of CNC cutting protocols.

And yet, as with so many digital works, the presence of the human hand was far from expunged. With assembly of the slices impossible to automate, the process relied heavily on a host of volunteers (mostly unemployed Southern European designers, the recession thus unwittingly funding the project) and thus the design of a tight informational system and managerial sequencing of tasks. The assembly process also revealed a wider truth about complex arboreal (and perhaps all) structures and their reliance upon broad collaboration between multiple agents. It recalled the astonishing inter-species alliances that occur under the ground, where fields of entirely separate roots agree to interlock and enmesh, and share resources.

KEY PROJECT DATA

WEB PAGES
Project Website (due updating):
http://www.mobileorchard.info/
atmos webpage on the project:
http://www.atmosstudio.com/Mobile-Orchard
atmos collection of videos on the project (due updating):
http://www.youtube.com/playlist?list=PLz6LhwhDR5pEGN_inDNuh3m4cxP4rE6PC&feature=mh_lolz

TIMELINE
Design Commission: Feb 2013
Fabrication: June 2013
Installation: June 24th—July 27th 2013

SITES (all City of London (Financial District), UK):
24th June: Paternoster Square, EC4M 7DY
1st July: Devonshire Square, EC2M 4TH
8th July: St Mary Axe, London EC3A 8EP

Fig. 12: Detail of integration of luminous LED strips within grain of trunk base. (Photo by Alex Haw / atmos)
15th July: New Street Square, London EC4A 3BF
22nd July: Finsbury Avenue Square, London EC2M 2PG
Map: http://goo.gl/maps/yuIzc

MATERIALS
600 8 x 4' sheets of 4 mm Latvian birch plywood
300 1250 x 2500 mm sheets of ‘Priplak’ Polypropylene (for leaves)
3 8 x 4' sheets of 1.2 mm aluminium (for secondary curved-folded branches)
22 3W IP65 LED micro-spotlights (Wibre)
90 m of 12 W/m IP65-rated LED strips (LEDLinear)
160 hours of CNC time

CREDITS

DESIGN: atmos: Alex Haw, Jeg Dudley, Natalie Chelliah, Xiaolin Gu, Maite Parisot, Juan Carlos Bueno, Adamantia (Mando) Keki, Miriam Fernandez
STRUCTURAL ENGINEERING: Blue Engineering
LIGHTING DESIGN: Arup
LIGHTING SPONSOR: Architectural FX / LEDLinear / Wibre
PLYWOOD SPONSOR: DHH Timber
FABRICATION: Nicholas Alexander + volunteers
LOGISTICS: Tellings Transport
CLIENT: City of London Festival
FESTIVAL TREE SPONSOR: Bloomberg
FUNDING PARTNER: Arts Council England
REAL ORCHARD TREES: YouGarden + The Worshipful Company of Fruiterers
MICROSITE WEB DESIGN: 8-fold
HOSTS: Broadgate Estates, Devonshire Square Management, Land Securities, 30 St Mary Axe Management Company Ltd (The Gherkin)

NOTES

1 Even if they were out of season in the United Kingdom, a fact that ruined early plans for gleaning and freeganism; further pages than available here would be required to expand on the ecological acceptability of pan-national, cross-seasonal fruit transport.


3 Ranging from just two Newton Metres at 50 mm-diameter limbs, to 32 Nm at 200 mm diameter.

4 Peter Thomas, Trees: Their Natural History (Cambridge: Cambridge University Press, 2000), p. 69; note that conifers do the opposite, ‘pushing’ their limbs into alignment.

5 Most underground tree roots extend far beyond (up to three times) the spread of their companion canopy above, yet occupy an extremely shallow pocket of soil; Thomas, 2000, p. 72.

6 Peter Thomas 2000 (see note 4), p. 106.

7 The arrangement of a single leaf at each node.


9 Thomas 2000 (see note 4), p. 30. Note that even homogeneous single-specie leaf arrays embed diversity: ‘leaves act as independent units, similar to a block of apartments’.

10 Some of the variables controlled by the extensive master parametric model include: programmatic constraints like lowest branch heights; step heights and positions, and position of crown seat; position of connection points between trunk base and trunk above; height; width, segmentation, twist and taper of trunk, including extent of deviation from pure spiral; thickness, number, position and depth of trunk tension rings; depth-to-cantilever ratios of branches, along with their deviation in plan and section, and location of their inflection points; depth, width and taper of their plugs in relation to trunk sockets, and the corresponding position and size of tension bolt holes and washer recesses opposite; adaptive bolt spacing and nut recessing, and intermediary location of recessed micro-spotlights and linear strip channels; and fabrication constraints including slice thickness, part labelling, part size and layering, and orientation, arraying and positioning of final pieces for CNC-cutting.

11 Research that would be continued in his Department of Medicine at University College London, with the first publication nine years later in the Philosophical Transactions titled ‘The Electromotive Properties of the Leaf of Dionaea in the Excited and Unexcited States’ (1892); J. Brian Ford, How Animals and Plants Feel and Communicate (New York: Fromm International, 1999), p. 191.

12 See, for instance, The Journal of Plant Signaling & Behavior (František Baluška, Stefano Mancuso, Tony Treiwavas, Dieter Volkman, eds.).

13 Thigmomony means responds to contact.


15 An organism enacting photosynthesis (also known as photoautotroph).

16 Thomas 2000 (see note 4), p. 94. ‘In a mixed hardwood forest, it is possible to get the roots of 4–7 trees below the same square metre of soil surface.’