# Serial Branches

## *Strategies to activate the performative capacity of naturally grown wooden form with contemporary information technology*

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**Abstract.** *The question whether contemporary information technology with its potential for individual fabrication allows for a new approach to the uniqueness that is offered to us by nature was discussed within a 8-day workshop. 19 students of KADK explored the performative potential of naturally angled and forked wood – a desired material until 19th century, but swept away by industrialization and its standardization of processes and materials.*
**Keywords.** *Wood construction; material performance; shape recognition; furniture; digital fabrication and construction.*

## INTRODUCTION

Until the 19th century, naturally grown wooden form was a desired material for the construction of ship bodies, almost entirely for Viking longships (Durham, 2002), carriages and sledges, but as well in an architectural context like Norwegian Stave Churches or Japanese roof constructions (Zwerger, 2012). Grown to angled or forked form, these pieces demonstrate an outstanding performance due to their internal fibre orientation. Hence they were sometimes even more costly than straight pieces. The dawn of industry and the accompanying standardization of all processes and materials pushed the high performative but individual aside. All organisms of a tree that opposed classification were henceforth considered as 'wood defects'— although they are by no means defects in the system of a tree. In architecture, this classification endures until today, where trees are rather used as "potent architectural symbol" (Heathcote, 1997) than as structural element.

Over the last decades, architects became aware that high performance comes through the ability to adapt to local conditions (Kolarevic, 2005). This is especially true for architecture and its related systems, where most buildings are unique objects. A computational understanding allows a general orientation towards non-standard approaches and is paralleled with massive progress in the understanding of material composition as well as the introduction of digital design and fabrication processes that can handle the making of the bespoke. Whereas machines of the industrial age are driven towards repetition and uniformity, techniques as 3d-scanning, parametric CAD software and digital fabrication allow us to address individualized elements. Can these approaches give us access again to the uniqueness offered to us by nature?

## MATERIAL APPROACH

Wood does not solely grow in unique geometries but comes as well with unique material properties. This is especially true for the branches – the focus of this paper. Branches might become an up-to-date ecological material when combined with contemporary information technology.

Whereas the trunk of a tree receives weight mainly from above (vertical loads) branches receive loads almost perpendicular to their main growth direction and structurally behave like cantilevers with a full-moment connection. In reaction to this load, softwood trees (conifers) develop reaction wood under compressive force at the lower side of the stem - called compression wood - while hardwood trees (angiosperms) develop reaction wood in tension at the upper side of the stem - named tension wood. Forked wood can be regarded as a high-tensile and elastic joint of high intelligence. Whereas a crotch might seem to be a simple split, its growths pattern creates an interweavement of fibres that provide stiffness and elasticity in multiple directions. The crotch can hence naturally accommodate load from various directions.

We got especially interested in hardwood forks, as they split into two approximately equal parts. This seemed to us closer to architectural applications than the softwood with its dominant trunk. However, in recent wood science, there is disagreement regarding the practicability of hardwood's tension wood. Shmulsky and Jones (2011) state that "strength of tension wood generally compares unfavorably with that of normal mature wood" and point out only the higher cellulose content and higher density, which "results in slightly improved chemical pulp yields". In contrast, using a different set of references, Barnett and Jeronimidis (2003) conclude that "mechanically, at least, tension wood is a better wood that normal", mainly limited by extensive shrinkage.

Pre-studies showed that the variation of the crotches' angles stays in a limited range for each species of tree. For instance, diverse branches from beech show differences of the forking angle of not more than 20°.

Our project was multidisciplinary initiated by a furniture manufacturer in cooperation with a carpenter and developed further within an 8-day workshop with 19 students of architecture at an Academy of Fine Arts. Our starting point was the speculation about assembly techniques and resulting objects:

- For which kind of objects can we use branches and assemblies of these?
- How can we especially employ the individual shapes of branches?
- To which extent should we transform the branches?

### *Into the woods*

For our workshop, we chose to focus on beech wood – first of all, because hardwoods like the beech have stronger branches than softwood and second, among the hardwood, beech is the most populous forest tree in Denmark (even mentioned in the Danish National Anthem).

Before the workshop, participants collected branches in the forest of Nødebo Skovskolen following personal preferences and agendas. In a first step, we collected without evaluating the branches' structural/material quality, just looking individually at form potentials and their visual appearances.

In a second step we categorized and negotiated the collected branches within the workshop group. This step initiated the discussion of the material variance process by registering the collected material through grouping and distinguishing their performative qualities, appearances and characteristics (uniqueness, 3D, 2D, Y-Shape, different angles, curved, linear etc.).

Subsequently, we reduced the grouped branches to three major categories – variations on Y-Shape, flatness (2D-branches) and uniqueness (3D-branches). While developing five different group projects, we identified two strategies to approach the branches.

## MATERIAL COMPUTATION

The first approach is based on advances in capturing, representation and fabrication of materials through digital techniques. The last decade has seen the emergence of a digital chain that links the design environment with fabrication. The creation of interfaces between design and production allows for instance to activate the potential of traditional wooden joinery to face challenges of contemporary timber architecture (Tamke and Ramsgard Thomsen, 2009).

Current research is suggesting a "new material practice" (Tamke et al., 2012) that extends the geometric understanding of material with a fixed set of material constants into the cognition and use of material behaviour. These approaches span from the design with bending behaviour in active bending structures (Lienhard et al., 2012) to the use of material to compute, coined by Menges (2012) as 'material computation': "In architecture, computation provides a powerful agency for both informing the design process through specific material behaviour and characteristics, and in turn informing the organisation of matter and material across multiple scales based on feedback with the environment."

These approaches rely inherently on the very detailed understanding and specification of the material behaviour of every element. In our case, the necessary knowledge about the material exceeds the existing definitions of material properties that are found through empirical testing across a series of elements.

### *How to compute branches?*

Branches have widely varying properties (therefore considered as 'wood defect'). Their individuality and inhomogeneity collides with a digital workflow that takes its point of departure in the capturing of an element's properties – which are not given for the branches. To capture a branch requires not only a recording of its form with tools that became very common lately, such as Microsoft Kinect (2010) or photogrammetric software. It requires as well non-destructive ways to formalize its specific physical, mechanical and chemical behaviour. First attempts to speculate about the design potentials of these parameters hidden in the material include x-ray scanning of timber (Yoshida, 2012) and the subsequent simulation of its elements' behaviour through a fine-grained simulation (Sørensen et al., 2008). However, these approaches are still in early stages based on costly scientific equipment (in case of the x-ray scanner even harmful).

During our workshop, we focused on the capturing and subsequent processing of geometrical data derived from the crotches (Figure 1), based on ideas to treat them as a building element with a defined angle. The registration of these angles allowed to determine a place for it in an overall assembly with a given design intent. The assembly of crotches with matching angles could become a procedure that could follows similar statistical strategies applied to limestone leftover pieces in the 'Smart Scrap'-project directed by Kevin Klinger at Ball State University. The CNC-fabrication of wooden joints would allow to connect the selected elements.

Within the workshop, we tested low-end approaches with a Microsoft Kinect scanner and subsequent approximation of the geometrical axis of the branches as well as detailed scanning using a Roland 3D laser scanner. The registration of a branch geometry turned out to be a substantial obstacle. Whereas the scanners could capture the geometry in a reliable way, the definition of axis lines – crucial for the application of joints – was difficult. Within the 'Prosthetic Branching' project (Figure 2), we put the cart before the horse: a 3D-scan of the crotches' ends served as negative for the interior shape of a clamp encompassing the whole end of the branch. Having a tight grip and perfect fit, this approach sets

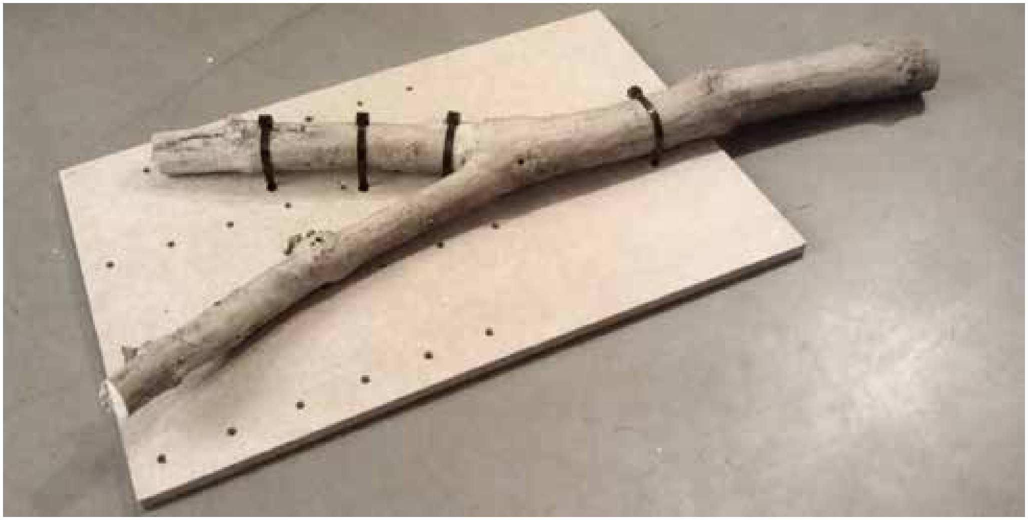

*Figure 1*
*Registration and processing of branches at KADK using a fixed registration plate.*

aside the idea to work specifically with the inhomogeneous crotch but works specifically for the crotch with a homogenous material like MDF. This well understood part negotiates between the ones from which knowledge can hardly be obtained.

## MATERIAL VARIANCE

In parallel to the digital tools, we had close look at the traditional way of processing naturally grown shape, as applied for instance to the construction of Viking longships or Japanese joinery. The geometry of the components was not defined numerically, but transferred directly by drawing on the wood without having been captured in absolute measurements. Benje (2002) writes: "The further the formation of the workpiece moved forward, the more important the actual piece became in comparison to the drawing." The dimensional reference of a component was not an absolute number, but the derivation of the hierarchically overlying or adjacent component. The dimensions were determined by deriving by drawing further and further. This is particularly evident in the wood joints: Components that have been processed with hand tools only interlock mutually, but are not interchangeable. In case of often needed geometries, jigs were applied for scribing, in which case the components relatively depend on the jig. In any case, the geometry of a wood compound is aligned relatively to the respective adjacent component (Schindler, 2009).

In our workshop, we first observed the boat builders at the Viking Ship Museum Roskilde applying this strategy, while proving their theories by testing them on full-scale reconstructions (Figure

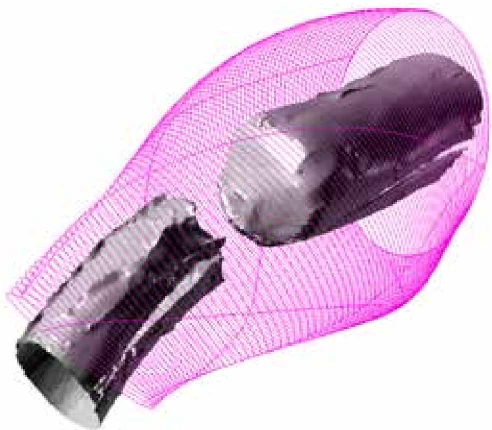

*Figure 2*
*'Prostethic Branching' created experimental joints whose functions were to form the merging pieces between a pair of branches. A detailed scan of the end of the crotches served as the negative for the interior shape of a clamp encompassing the whole end of the branch. The joint were milled in MDF on a 3-axis-router. (L K Madsen , V A Velarde, H Martinez, M Giodice)*

*Figure 3*
*The form of a jig for a Viking longship rib applied to a naturally grown fork (Viking Ship Museum Roskilde).*

3). Later we experienced in our own projects, that the grown wood's geometry could not be properly measured with our digital scanning devices and everything had to be continually adjusted with hand-tools on-site (for instance, Figure 2 'Prostethic Branching', Figure 8 'Triangulated Branches'). The 'Interpretations of a Formal Grid Structure'-project (Figure 4) followed another approach: Instead of modifying the branches, a joint with high tolerance was developed. The 'Optical Joints'-project (Figure 5) avoided the topic with an elegant artistic strategy: The construction consists of a single branch that is reflected in various mirrors without any joint – a strategy that can not be materialised with branches, but visualised as a 3D-model from a scanned branch and brought back to reality with a 3D-printer.

At that point we wondered whether capturing as much data as possible was an adequate way of dealing with the branch geometry – what would be the result if we tried to limit the amount of necessary information to the minimum? Consequently, we asked for design approaches that take the natural variation into account by considering unusual high tolerances and defining as few measurements as possible? These questions led us directly to an unconventional fabrication strategy: Taking on an approach developed by carpenter Martin Bereuter for a competition entry at 'Handwerk+Form' in 2012, we planed the branches on both sides with a mechanical planer that could measure the remaining material thickness with a precision of 1/10 mm. This process results in two parallel surfaces with a defined distance – all other measurements remain unknown (Figure 6).

The approach was tested on two studies: In the 'Branch Stool', a CNC-milled seating surface comes with three groves, into which the planed branches with corresponding material thickness are inserted (Figure 7). The 'Triangulated Branches' project followed the same approach: a planed branch is described by its material thickness and three points of an outline-triangle drawn around it (Figure 8), making it a triangular geometry. In both projects, the exact shape of the branch can be disregarded as long as it stays within a defined tolerance.

## CONCLUSIONS

Our research shows that the handling and manufacturing of branches challenges our understanding of design and production processes. Although

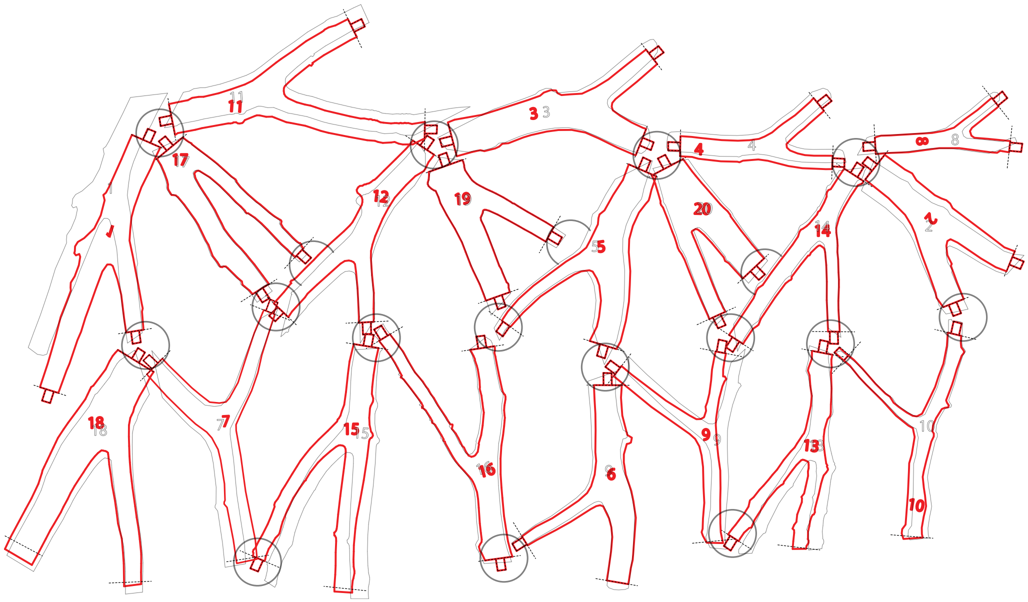


*Figure 4*
*'Interpretations of a Formal Grid Structure' look for the formal logic of natural branches with their organic shapes. This project explored what happens if you force the branches into behaving like a formal grid structure? The process was developed through mapping and capturing Y-Shape branches in 2D and further working with them as outlined silhouettes to explore their potentials as elements in a grid based structures. (L Nguyen, A Korsgaard, A Bergqvist, A-L Capaul)*

we claim to explore the benefits of digital tools, our thinking is bound to the heritage of industrialization: We are used to work with measureable geometry, minimal tolerance and reliable material constraints. Consequently, we faced unexpected obstacles in developing smooth digital chains from scanning to production (i.e. mismatching branches and customized joints). We had to question our convictions and use our tools in unconventional ways to demonstrate avenues to approach the branches.

## Capture

In our workshop, we made an attempt to capture form of grown materials. It would have been even more demanding to include a grown material's behavioural properties into a parametric model, as required for a 'material computation'-strategy – standardized material constraints like they can be retrieved for derived timber products do hardly exist for grown material. To understand a material's properties, tools for non-destructive determination of mechanical and physical characteristics are required. While we can only speculate about potential links between x-ray scanning and detection of simulated behaviour, 2D- and 3D-scanners for the reception of surface and volume became accessible in a way that was beyond our imagination a few years back. But

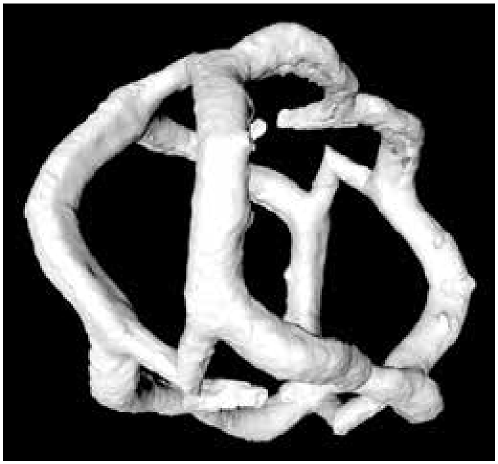

*Figure 5*
*'Optical joints' investigated how naturally grown shapes could tessellate into structural repetitive patterns and closed shapes by experimenting with optically joining individual unique branches into serial mirrored repetitions. The process started with 3D-scanning and further developed an experimental structure by mirroring with real mirrors as well as with 3D-modelling software, materializing the serial branch with a 3D-printer. (C S Svejstrup Vindahl, L E Rajakorpi, M Byung Simonsen, C Wraae Jensen).*

Figure 6
*Individual branches only captured by the distance between two planed parallel surfaces (M Bereuter).*

even with that restraint to geometry we found that our existing set of techniques and especially our industrial mind-set is challenged.

## *Scope of Applications*

The resulting range of case studies ranked from joint studies, construction systems and ergonomic studies to applicable pieces of furniture, but did not yet enter the realm of building scale.

During the workshop we found it quite demanding to develop adequate applications for the branches. Especially functionality was hardly aspired

*Figure 7*
*The 'Branch Stool' consists of a CNC-milled seating surface with three groves, into which planed branches with a corresponding material thickness are inserted, 'Serial Branches' exhibition at ggggallery Copenhagen, 16.11.2012–16.02.2013 (C Schindler).*

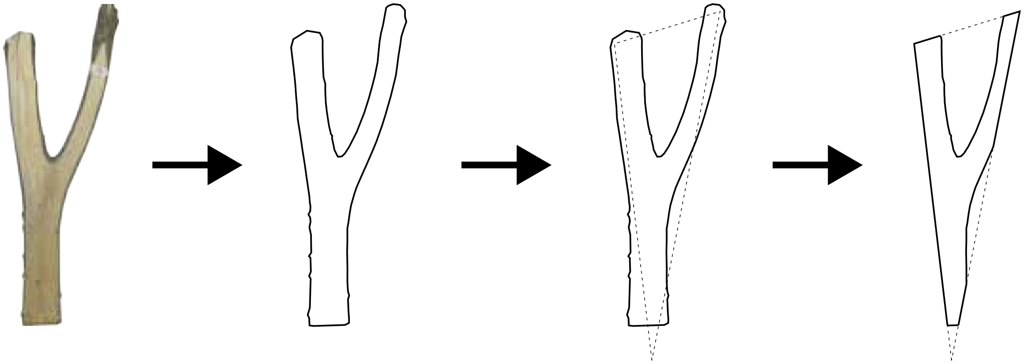

*Figure 8*
*'Triangulated Branches' explored the potentials within using branches as elements in a triangulated polygonal surface through registering each Y-Shaped branch by its bounding-box fitting in a triangle of the controlled polygonal surface. Each branch was further processed and flattened with two parallel surfaces for making it more convenient to work with in standard wood-shop machinery (A Brunvoll, A Bergqvist, A Schumann, M Bhuvanendra).*

as most groups decided for an approach without a direct functional claim. However, if we look at our highly functional traditional examples like the Viking longship, we predict that there are applications for naturally grown wood that go further. It would not be the first time that groundbreaking technologies are at first employed to facilitate established design concepts and construction logic (Menges 2008).

## OUTLOOK

The workshop inspired us to explore further the performative nature of wood. The KADK CITA project 'The Rise' (on display at EDF gallery in Paris until end of October 2013) took a point of departure in the complex yet highly effective way that nature invented to branch. Employing bundling of rattan a fibrous structure that branches three-dimensionally is created. The different forces between the nodes are balanced using 'active bending' techniques and speculate about a performative architecture based on fibres.

A second follow-up project currently conducted at ETH focuses on the yew tree, a specific material that was the wood of choice for the English longbow. It is characterized among other things by its twisted and knotty growth, elasticity and extreme colour difference between sapwood and heartwood. Therefore, from an industrial perspective, the whole tree is a 'wood defect' what makes it even more tempting for our approach.

## REFERENCES


Barnett, J R and Jeronimidis G 2003, 'Reaction wood' in Barnett R and Jeronimidis, G (eds) 2003, *Wood quality and its biological basis*, Blackwell Publishing, Oxford, pp. 118-136

Benje P (2002), *Maschinelle Holzbearbeitung: ihre Einführung und die Auswirkungen auf Betriebsformen, Produkte und Fertigung im Tischlereigewerbe während des 19. Jahrhunderts in Deutschland*. Wissenschaftliche Buchgesellschaft, Darmstadt

Durham, K 2002, *Viking Longship*, Osprey Publishing, Oxford

Heathcote, E 1997, 'Imre Macovecz – The Wings of the Soul', *AD Architectural Design* Vol. 47, Wiley, London

Kolarevic B 2005, *Performative Architecture - Beyond Instrumentality*, Spoon Press

Kwinter S 2003, 'The Computational Fallacy', in *Thresholds – Denatured*, No 26. Massachusetts Institute of Technology

Lienhard J, Alpermann H, Gengnagel C, Knippers J 2012, 'Active Bending, a Review on structures where bending is used as a self formation process', *Conference Proceedings IASS–APCS From Spatial Structures to Space Structures*, Seoul, South Korea

Menges A 2008, 'Integral Formation and Materialisation – Computational Form and Material Gestalt', in Kolarevic B and Klinger K (eds), *Manufacturing Material Effects: Rethinking Design and Making in Architecture*, Taylor & Francis Books, New York, pp. 195–210

Menges A 2012, 'Material Computation: Higher Integration in Morphogenetic Design', *AD Architectural Design*, Vol. 82 No. 2, Wiley, London

Schindler C 2009, *Ein architektonisches Periodisierungsmodell anhand fertigungstechnischer Kriterien, dargestellt am Beispiel des Holzbaus*, Dissertation ETH Zurich No 18605

Shmulsky R and Jones, P D 2011, *Forest Products and Wood Science – An Introduction*. 6th ed., Wiley-Blackwell, Chichester

Sørensen B F, Gamstedt, E K, Østergaard, R C, Goutianos, S 2008, 'Micromechanical model of cross-over fibre bridging – Prediction of mixed mode bridging laws', *Mechanics of Materials* 40 (2008), pp. 220-234.

Tamke M, Ramsgard Thomsen M 2009, 'Digital Wood Craft', *Proceeding to the CAAD Futures 09 Conference - Joining Languages, Cultures and Visions*, Montreal, Canada, pp. 673-683

Tamke M et al. 2012, 'A new Material Practice – Integrating Design and Material Behavior', *Proceedings of Symposium on Simulation for Architecture and Urban Design (SimAUD)*, Orlando, USA, pp. 5–12

Yoshida H 2012, 'Bridging Synthetic and Organic Materiality: Gradient Transitions in Material Connections.' in *Biologically-Inspired Computing for the Arts: Scientific Data through Graphics.* IGI Global, Hershey, pp. 81–88.

Zwerger K 2012, *Wood and Wood Joints : Building Traditions of Europe, Japan and China*, Birkhäuser, Basel